LAND USE DEVELOPMENT AT INTERSTATE INTERCHANGES IN INDIANA

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BY

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JHRP

JOINT HIGHWAY RESEARCH PROJECT

PURDUE UNIVERSITY AND

INDIANA STATE HIGHWAY COMMISSION

Final Report

LAND USE DEVELOPMENT AT INTERSTATE INTERCHANGES IN INDIANA

TO:	J. F. McLaughlin, Director Joint Highway Research Project	May 3, 1973
		File: 3-8-4
FROM:	H. L. Michael, Associate Director Joint Highway Research Project	Project: C-36-70D

The attached Final Report has been prepared by Mr. Lawrence P. Fabbroni, graduate Assistant in Research on our staff, under the direction of Professor G. T. Satterly, Jr. The Report is titled "Land Use Development at Interstate Interchanges in Indiana" and was also used by Mr. Fabbroni as his thesis for the MSCE degree.

The purpose of the study was to determine the extent of land use development, land use change and land use control at Interstate interchanges. Much land use development primarily road user services types, was found at many interchanges. Land use control was found to be virtually nonexistant. One of the major benefits of the research is demonstration of how realistic application of land use planning and controls at interchanges could be developed to the advantage of road users, developers and the community.

The Report is presented for acceptance as fulfillment of the objectives of the Study.

Respectfully submitted,

Harold L. Michael

Harold L. Michael
Associate Director

HLM:ms

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by

Lawrence P. Fabbroni
Graduate Assistant in Research

Joint Highway Research Project

File: 3-8-4

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Conducted by

Joint Highway Research Project
Engineering Experiment Station
Purdue University

In Cooperation With

Indiana State Highway Commission

Purdue University
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No amount of thanks can suffice in recognizing the encouragement and motivation my family has provided me during this research effort.

The esteem of the author goes to Dr. Gilbert T. Satterly of the School of Civil Engineering for his major review and constructive comments throughout the study; to Professor Robert D. Miles for his help and his guidance; to Dr. William Grecco for his substantial input; to Professor Harold L. Michael for his review and his encouragement; and to Dr. W. J. Studden, Department of Mathematics and Statistics for his review.

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Final thanks are extended to all Traffic Lab Graduate Students, particularly, A. Hobeika, W. McGuirk, T. Butcher, D. Ripple, and M. Herman; to my typist, Miss Jane Pierce; and to all the Traffic Lab Draftsmen.

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ABSTRACT

Fabbroni, Lawrence Peter. M.S.C.E., Purdue University, December 1972. Land Use Development at Interstate Interchanges in Indiana. Major Professor: Dr. Gilbert T. Satterly.

The purpose of this research project was to determine the extent of land use development, land use change, and land use control at Interstate interchanges open to traffic for more than two years. Results of the inventories and the aggregate land use development magnitude model should enable highway planners to pinpoint existing areas requiring immediate comprehensive interchange land use planning and to refer to typical development trends in planning for new interchanges along limited access roadways.

Data was gathered from secondary sources available at the ISHC, the Indianapolis DOT, and the Indiana Department of Commerce Bureau of Planning, and from in-field interviewing and surveys.

Road user services were found to constitute the bulk of early post interchange opening development. Residential, commercial, and industrial land uses, while increasing in area coverage as the nearby urban center sizes increase, occurred before, during, or after Interstate opening depending on the extent of urban growth out to the Interstate and interchanges when first opened. Land use control was found to be virtually non-existent; but, the portions of the interchange area which were planned and controlled were accumulated in a land use control listing whose realistic application is demonstrated in a sample of how an existing interchange area might be developed for the benefit of road users, developers, and planners if planning through a land use control package is effectively implemented early.

CHAPTER I
INTRODUCTION

The United States has planned, designed, financed and constructed a significantly improved and comprehensive transportation network since 1956. Many of the improvements will connect formerly scattered and sometimes isolated transportation routes. 42,500 Interstate miles designed and built to freeway standards will be part of the final comprehensive transportation system.

Since "transportation improvement shifts the comparative advantages of places," (6) existing cities are growing and major economic activities simultaneously shifting toward the new freeways. Therefore, freeway design characteristics, most notably limited access and grade separation, have created new magnets for land uses, especially those uses necessary to travelers, at the selectively placed freeway interchanges.

Highway planners and designers have realized for over a decade that "interchanges can serve as an instrument to open up new areas for sound economic growth, to revive the economic vigor of places that need economic revival and perhaps to be the nucleus for a new kind of community." (25)

This study has determined what land use growth has occurred at Indiana freeway interchanges since their opening and what land use, design, or traffic controls have been implemented in planning interchange areas.

Scope

This is a study of interchange area development for Indiana interchanges open more than two years before January 1972. The interchanges included in the survey are as follows:

Interstate Route 65 Interchanges from the State Route 334 Interchange northwest to the State Route 52 Interchange.

Interstate Route 65 Interchanges from the US 24 Interchange north to the US 30 Interchange.

Interstate Route 69 Interchanges from the State Route 9 Interchange north to the US27 Interchange near the Michigan border.

Interstate Route 65 Interchanges from the US 31 Interchange south to the State Route 131 Interchange.

Interstate Route 70 Interchanges from the Post Road Interchange east to the US 40 Interchange.

Interstate Route 70 Interchanges from the State Route 267 Interchange west to the US 40 Interchange.

Interstate Route 74 Interchanges from the Post Road Interchange east to the US 52 Interchange.

Interstate Route 74 Interchanges from the State Route 267 Interchange west to the State Route 63 Interchange.

All other interchanges in Indiana were excluded from consideration for reasons of interchange age, of extensive traffic redistribution in the area as occurred on I-465 South when I-465 North opened, of existing saturated urban development, or of unique route location, route operation, or route interconnection. Development for a mile along the crossroute on both sides of the Interstate interchange was considered as being the interchange area.

Goals

This study has determined the change in land use at Indiana Interstate interchanges since their opening and has suggested controls for interchange area land use development.

Objectives

Land use development trends and land use magnitudes were quantitatively summarized by aggregate summaries and by selected case studies. Land use, design, and traffic controls were inventoried and compared through case studies for effectiveness.

Need For Study

If we continue the dangerous pattern of piece by piece development in our new and future interchange areas, the end product will surely be blighted, unattractive strip development with excessive access points, with insufficient building setbacks, inadequate parking and unloading areas, and excessive traffic generation. The aftermath of urban bypasses should be enough evidence that unplanned crossroutes interchanging with our new freeways can follow a similar strip development course. "The danger is very real that the facilities serving Interstate system interchanges will become functionally obsolete through development of land uses that generate traffic exceeding their design capacities." (20)

This research fills a gap for Indiana by presenting actual land use development conditions at Interstate interchanges with a general methodology for controlling future development.

CHAPTER II
PAST RESEARCH IN THIS AREA

In 1961 a Highway Research Board Symposium (13) on Interstate interchange development and land use control stimulated states' interests in helping localities develop interchange area plans. Subsequently, many states including Indiana (9) issued interchange area planning brochures briefly explaining the importance of interchange planning by local planning commissions or groups and how to utilize state aid of funds or of manpower to act on early policy making for interchanges. There was some follow-up by local Indiana jurisdictions with a study on planning orderly Lake County Interstate interchange area growth (14) as an example.

To plan for orderly growth all such studies must ideally make a sound prediction of the amount and type of interchange land use development. Adequate prediction of development along the crossroute in the interchange area would provide a partial measure of interchange benefits while forewarning of needed land use controls to maintain efficient development in the future.

In several states the first predictive step after delimiting the interchange area, and establishing goals and objectives for their development study, has been a complete inventory of existing development at all interchanges. A study at the University of Tennessee (22) determined the property tracts, property sales, and property use at 74 interchanges along I-40 between Memphis and Knoxville in Tennessee. Similarily, Barton-Aschman Associates, Inc. surveyed Illinois Interstate interchanges throughout the state and subsequently selected critical areas for further case study.

The continuum from general survey to specific studies has progressed to different extents in many states. Most notably, Pennsylvania State University, after completing a Manual for Interchange Area Planning has carried on continuous case study work on physical, social, and economic impacts of Interstate interchanges at the Institute for Research on Land and Water Resources. Eyerly has studied the formation of new properties, changes in real estate values, changes in land use and reasons for change

at selected interchanges (4). Saulender and others (21) studied economic impact of selected interchanges. Dansereau and his associates (3) looked at social aspects, such as education, occupation, and socioeconomic status of interchange communities.

Utah developed an instructional manual from a detailed survey of thirteen randomly selected interchange areas (26). The Ohio State Highway Department (18) and the Wisconsin State Highway Department (23) have each done impact studies on selected Interstate interchanges. A Michigan study considered interchanges along I-94 to determine development success by by interchange quadrant, by interchange type, and by interchange location (2).

While working for state or for federal agencies, several individuals have become interested in studying interchange area development factors. Kuhn of the University of Wisconsin, while looking at the entire planning problem of predicting probable development, of estimating resultant generation by development type, and of devising suitable legal controls, has concentrated his detailed work primarily on trip generation by type of establishment. His detailed road user interviewing at sixteen interchanges indicated preference for interchanges and particular land uses according to factors, such as, quadrant location, site availability, interchange type, major oil company brand availatility, and user familiarity with the area (12). Theil (25), while stressing economic control planning aspects, compiled an extensive list of factors leading to Interstate interchange development. This list adds population of the interchange area, traffic on the feeder crossroad, age of the interchange, freeway capacity, and land area available for development to Kuhn's factors mentioned above. Garrison structured his view of interchange area development as being a system whereby individuals, private firms, and government agencies locate with a common economic efficiency objective (5).

All these studies by states and individuals have collected data on many interchanges concerning development. As a prime objective or often as a byproduct of inventory research, suggested explanatory variables for interchange development have evolved. However, presently no known researcher has collected sufficient data to model interchange land development based on factors believed to cause such growth. Mason in Alabama (16) hopes to use annual photographs of Alabama Interstate

interchanges, taken each of the past seven years, to explain the type and rate of development at interchanges by using 1970 Census information as social, economic, and demographic independent variables in a multiple regression model. Kuhn is also reaching the point where his data bank will allow alternative models of customer generation by type to be tested.

CHAPTER III
CONCEPTUAL BASIS

Delimitation

This study was concerned with the development around Interstate interchange areas. A survey of other reports and handbooks on interchange studies conducted in other states establishes a common range of areas from within a one-half mile radius to within a mile radius of each interchange. After preliminary inspection of land use development through aerial photographs and through general field inspection this Indiana interchange study considered only that development for one mile on both sides of the Interstate interchange and visible from the crossroute.

The interchange population is composed of all interchanges not judged to be extensively developed before interchange construction as with a right of way through an existing urban community, not in an area of highly unstable travel patterns and of land development as with the circumferential route at Indianapolis, and not with unique peculiarities by virtue of route location or of interchange type, as with I-64 interchanges or with freeway to freeway interchanges respectively.

A Conceptual Approach To The Model Hypothesized

The interchange area boundary was considered to be the boundary for the interchange area system. A change in that system's state can occur when an activity, communication, or channel crosses the boundary and enters the system (input), when an activity, communication, or channel experiences change within the system (intra), or when an activity, communication, or channel crosses the system boundary and leaves the system (output).

The state or response variable modeled is the magnitude of road user type development within the interchange system. The input-induced change in development is principally caused by movement of an

establishment into the interchange area system. The intra-induced change comes about through expansion of existing development, consolidation, or temporary closing of establishments. The output would come with increased advantage in other developing locations over time making abandonment of the present prime interchange area system economically desirable.

The independent factors in the model are also hypothesized according to the input, intra, and output system interactions defined above. With a discrete magnitude describing the state of a system, the system interactions described by independent factors are quantified at a corresponding level of detail for inclusion in the model. For instance, Average Annual DailyTraffic is used as a measure for channel usage outside, across, or within the interchange system boundaries rather than refinement to seasonal or hourly absolute volumes.

With the system, state of the system, and level of aggregation all introduced, the spectrum of causal factors producing a change of state are hypothesized to come from three main categories, the road user, the business developer or manager, and interchange characteristics.

Crossroute volume is indicative of road user activity within the capacity constraints of the channel across and within the system boundaries. Crossroute volume can be input, intra, or output in producing change in the magnitude of development of the interchange system. As input to the system, crossroute volume represents a consumer market whose needs can be potentially satisfied by road user services within the interchange area system. In addition to a roadway to parking exchange at the driveways, a crossroute to Interchange exchange can be initiated at the ramp terminals within the interchange area system. The third alternative for crossroute volume is the road user traveling through the interchange area without an inner system destination.

Off ramp volumes are hypothesized to indicate a potential for road user input to the interchange area system as a forced input created by lack of services on the Interstate facility. Although a mathematical component of the crossroute volume, the ramp volume,

constituting a distinctive captive market for road user establishments, is treated as a separate and independent factor.

Of the factors considered by business owners in establishing an enterprise within the interchange area system, the economic climate of a location is the major criteria. This climate includes changes in the environment external to the interchange area system. For instance, cities along the crossroute but outside of the interchange area are expanding and while growth has been shown to be reflected in the increased crossroute volume, the nearness and the size of the urban growth are hypothesized as causes of differing magnitudes of road user development in nearby interchange systems. Because, as population growth promotes economic growth, this economic growth may or may not occur within the interchange area system depending on urban area nearness and size. So accessibility measured by time from interchange to urban center and attractiveness measured by population or change in population appear to be valid independent factors to be tried separately or in combination in modeling road user development magnitudes.

While accessibility and attractiveness can account for interchange area market potential and market shift from old parallel routes, the neighboring interchange area system's magnitudes of development and nearness can not be ignored as measures of competition.

Finally, the characteristics of the interchange area system itself should be considered as possible factors affecting the state of the system from within (intra). These factors are interchange design type, age of interchange, age of Interstate, and the nature of the interchange location as either agricultural, suburban, or urban.

The interchange area as a system whose road user developments can be modeled by aggregate measures of road user patronage, of economic business desirability, and of interchange attributes constitutes this report's conceptual basis for analysis. This research is exploratory for Indiana in establishing development and proper controls for interchange areas with the look toward better implementation of interchange area planning, design, and operation in the future.

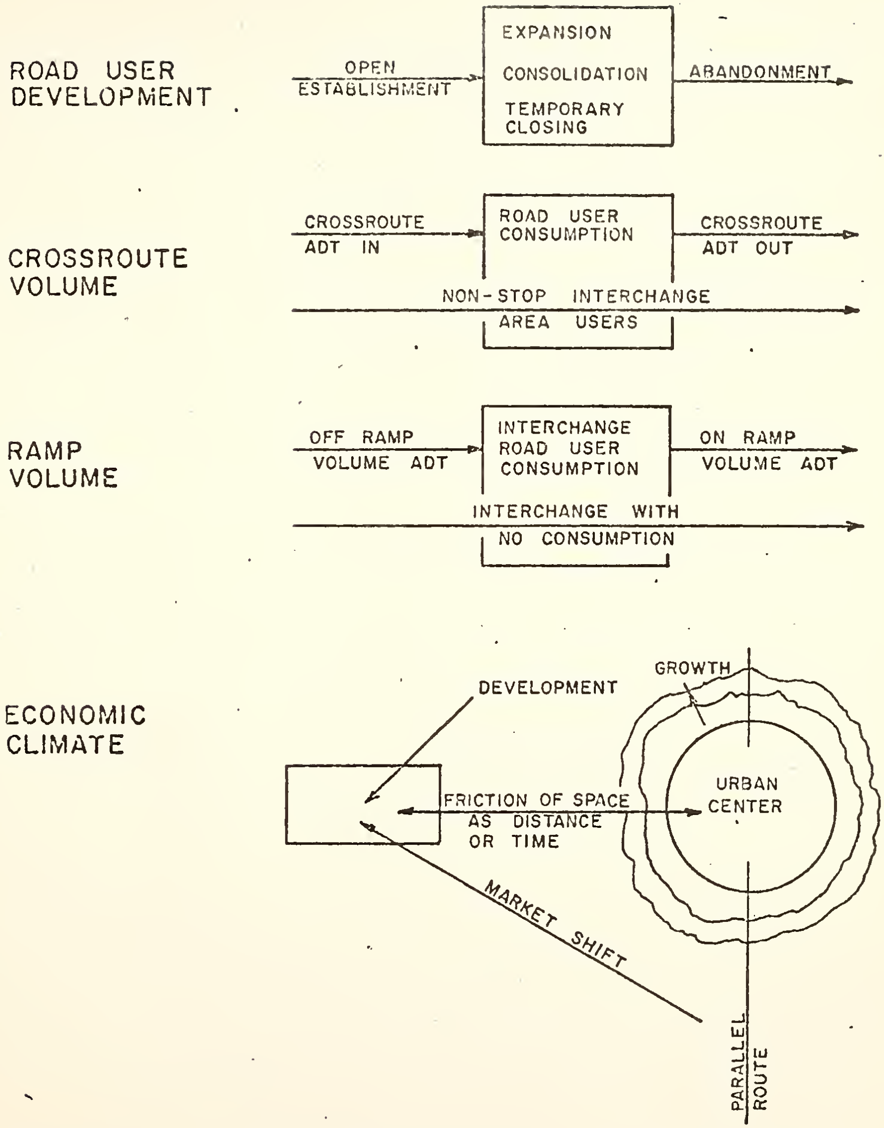
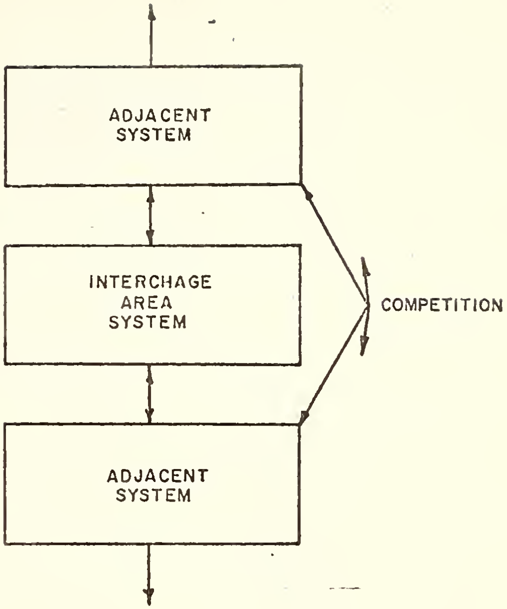


FIGURE 1. INTERCHANGE AREA SYSTEM LOGIC DIAGRAM

COMPETITION



INTERCHANGE
CHARACTERISTICS

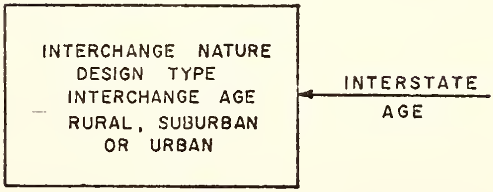


FIGURE 2. INTERCHANGE AREA SYSTEM LOGIC DIAGRAMS CONTINUED

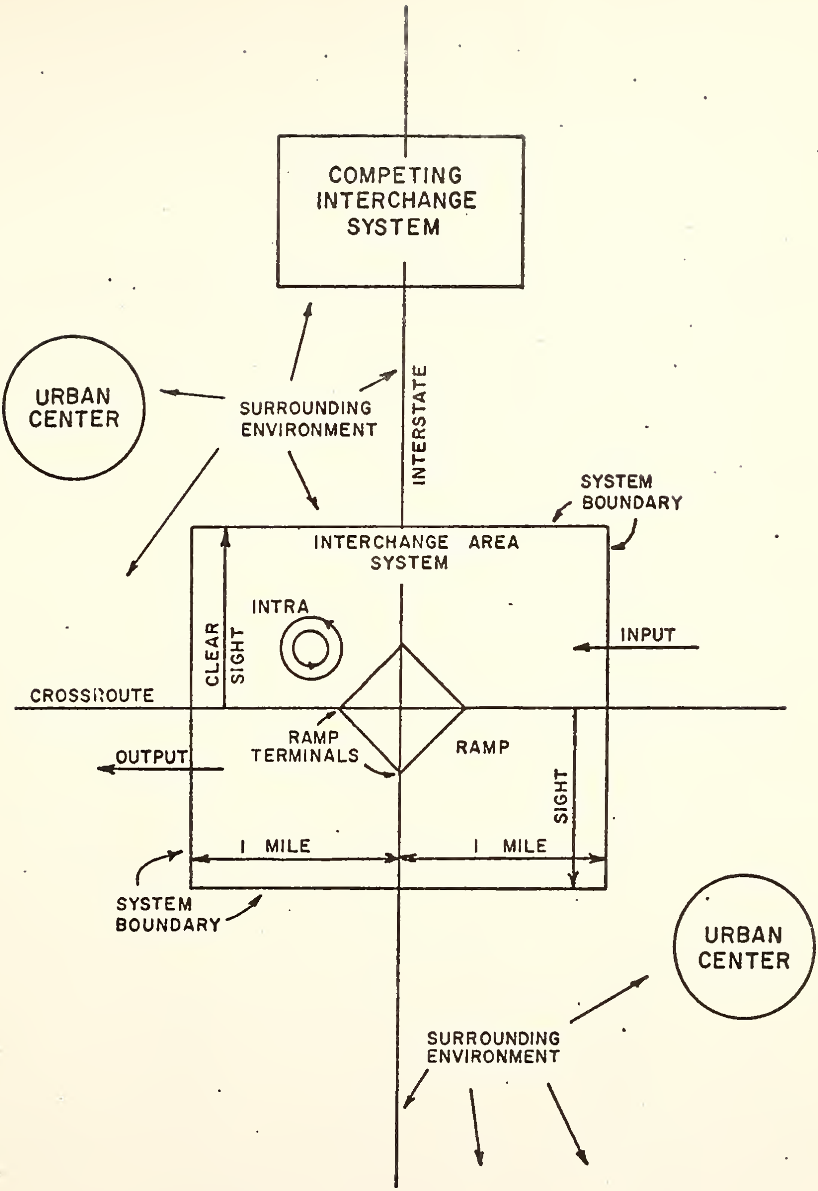


FIGURE 3. OVERALL SYSTEM DIAGRAM

CHAPTER IV
DATA COLLECTION

Data Inventory

A random sample was chosen from the 102 interchange population by randomly ordering each interchange and subsequently randomly numbering the random order. The total sample of interchanges was thirty-three or approximately thirty percent of the interchange population. This sampling procedure was used to chose those interchanges which as a subpopulation were felt to be representative of the entire interchange population.

The aerial photography for different periods of development of the sampled interchange areas was studied through the cooperation of the Photolab of the Aerial Photography Department of the Indiana State Highway Commission in Indianapolis. The photography is flown periodically for the United States Geological Survey and on a special project basis for the Indiana State Highway Commission.

After inspection of photographic sequences for seven interchanges of the random sample as flown periodically since 1956, a few shortcomings of using aerial photography became apparent. Since the entire state is not photographed in any one year there is a problem in quantitatively studying growth from data for different interchanges at staggered time intervals. For instance, if a Before and After Study on interchange area road user establishment growth were undertaken, there is insufficient photography for the interchange areas sampled to study a given time before and a given time after each interchange opening. Similarily, if development trends were to be studied dynamically over time, photography at equal intervals after opening for all sampled interchanges is unavailable. Advance planning similar to that for an ongoing Alabama study (16) to shoot annual photography of interchanges after opening is necessary to render aerial photography useful for time series studies. Additionally, in sparser developed areas

parcel identification by boundary lines of the area bought, as contrasted with the area utilized by investors is very difficult, if not impossible, to identify. Area of ownership and area of utilization are both important background to anticipate the extent of development possible in an interchange area with as yet undeveloped tracts and to anticipate further development by owners already operating road user services. An example of expansion which must be anticipated is an oil company which opens a gas station primarily for automobile service, follows with a restaurant addition, and eventually expands to handle trucks or there is a motel with an initial sixty-unit building investment but with adequate additional site area to add sixty units and also build a night club and two office towers.

Although abandoned, the preliminary photographic work with the seven interchanges mentioned above was the basis for an emphasis shift to studying road user development at all 102 interchanges of the interchange population, rather than a random sample.

Since establishment opening dates and land area of road user establishments were needed to describe trends and extent of development, driveway permits for any establishment desiring direct access to a State Highway crossroute within the interchange area were next sought. All such permits should be centrally housed in the Indiana State Highway Commission files.

Each permit specifies information on the proposed development's area and often is accompanied by a sketch showing the location of proposed structures or improvements, such as, drainage fields, water wells, gasoline pumps, areas for parking, buildings, light and advertisement towers, driveways, and necessary culverts. The better plans show driveway and lot line proximity to the Interstate right of way, to the Interstate center line, and to the closest Interstate ramp terminal. However, the dates on the permits and the permit records of land development often differ greatly with actual field development dates and field development respectively. Actual opening field dates were found to lag the date of permit review by one year. Also, as an example of the inadequate permit correlation with actual development, of the permits located on file for all establishments at the Interstate

interchanges between Anderson and the Michigan State line along I-69, roughly half are not built. Furthermore, half of those found in a field study of that stretch on I-69 were not on file in the state office.

This determination made it clear that the permits could not be used as a sole source of data and that a comprehensive field survey was necessary.

The field survey was conducted during January 1972 by one interviewer. The purposes of the survey were to inventory development in the interchange area systems as of January 1972, to determine the sequence of development up until that time, and to get a field impression of the interchange or crossroute performance problems, if any, that existing or anticipated development might cause, now or in the near future. These objectives were met by utilizing a three source survey consisting of a sketch map, an interview, and a mail-in questionnaire (Appendix B). A Sketch map of establishments and approximate position with respect to the Interstate ramps for each interchange was done by a windshield survey with the aid of an odometer. An interview was conducted to determine the first opening date of the establishment. When the person interviewed could not answer the question concerning original opening, the simple questionnaire with cover letter was left to be completed and returned by mail. Of fifteen questionnaires distributed ten were returned. An accuracy check on unsure field responses by questioning adjacent owners or managers concerning a neighbor's founding date corresponded within six months in most cases. Where refusal to answer or an inability to answer or to contact someone who could answer was encountered, the permit date adjusted by an average year building lag was used. A total of 370 interviews were conducted in this phase of the study.

Figures 4 through 12 show the results of the field survey by units of land use types as defined in Appendix A. As may be noted in that Appendix, non-road user land uses, such as, residential and industrial land uses are very crudely estimated.

■	TRUCK STOP
●	MOTEL
+	RESTAURANT
P	RECREATION PARK
O	TRAILER PARK
Φ	MOBILE HOME SALES
Z	PUBLIC FACILITIES
⊕	FOOD SERVICE
▲	BUSINESS ESTABLISHMENT
△	SERVICE STATION
□	INDUSTRY (or REGIONAL OFFICE)
🅂	NEIGHBORHOOD SHOPPING CENTER
Ⓢ	REGIONAL SHOPPING CENTER
🅁	LOW DENSITY RESIDENTIAL
Ⓡ	MEDIUM DENSITY RESIDENTIAL
E	EDUCATIONAL (School)
*	INTERCHANGE FIELD SURVEY NOT 100% INCLUSIVE FOR PHASE I DATA COLLECTION. ALL ESTABLISHMENTS AT INTERCHANGES SO DESIGNATED ARE NOT SHOWN AS A FULL INVENTORY WAS ONLY TAKEN OF RURAL INTERCHANGES DURING PHASE I.

FIGURE 4. INTERCHANGE AREA DEVELOPMENT SYMBOL CODE

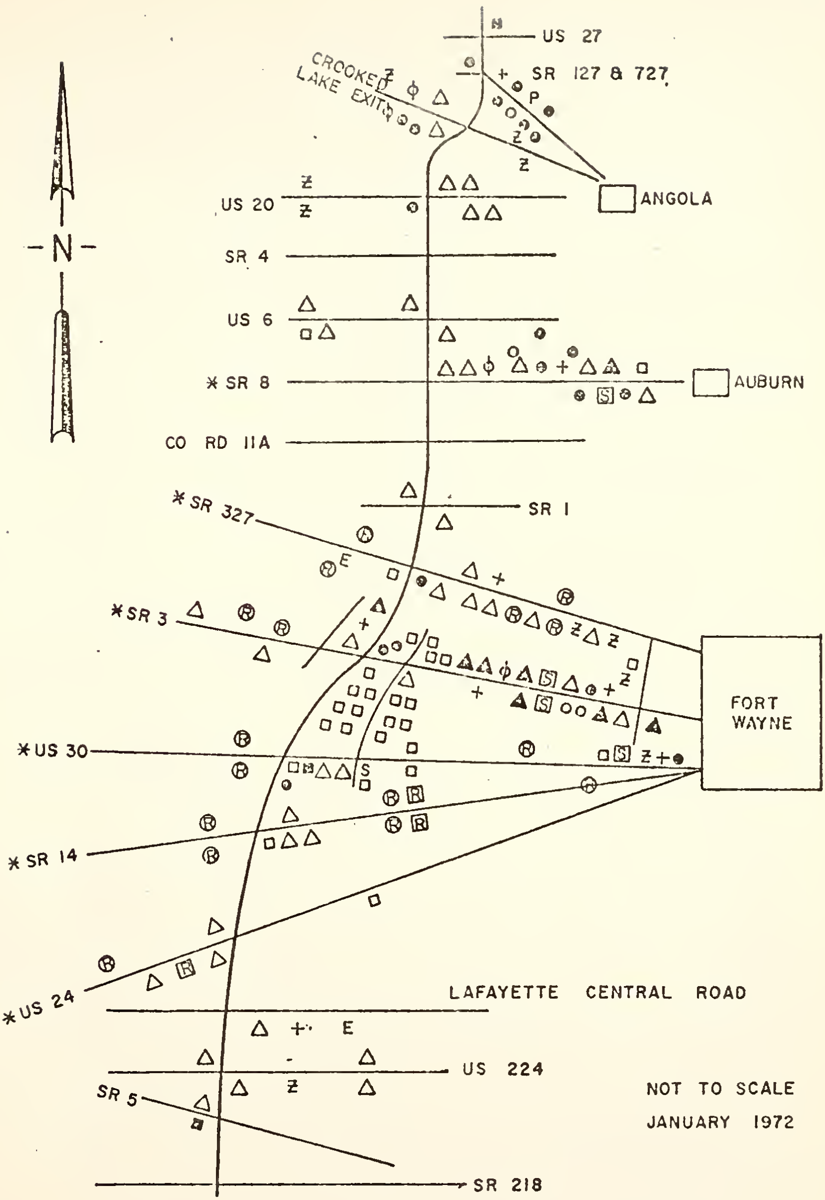


FIGURE 5. INTERSTATE 69 INTERCHANGE DEVELOPMENT

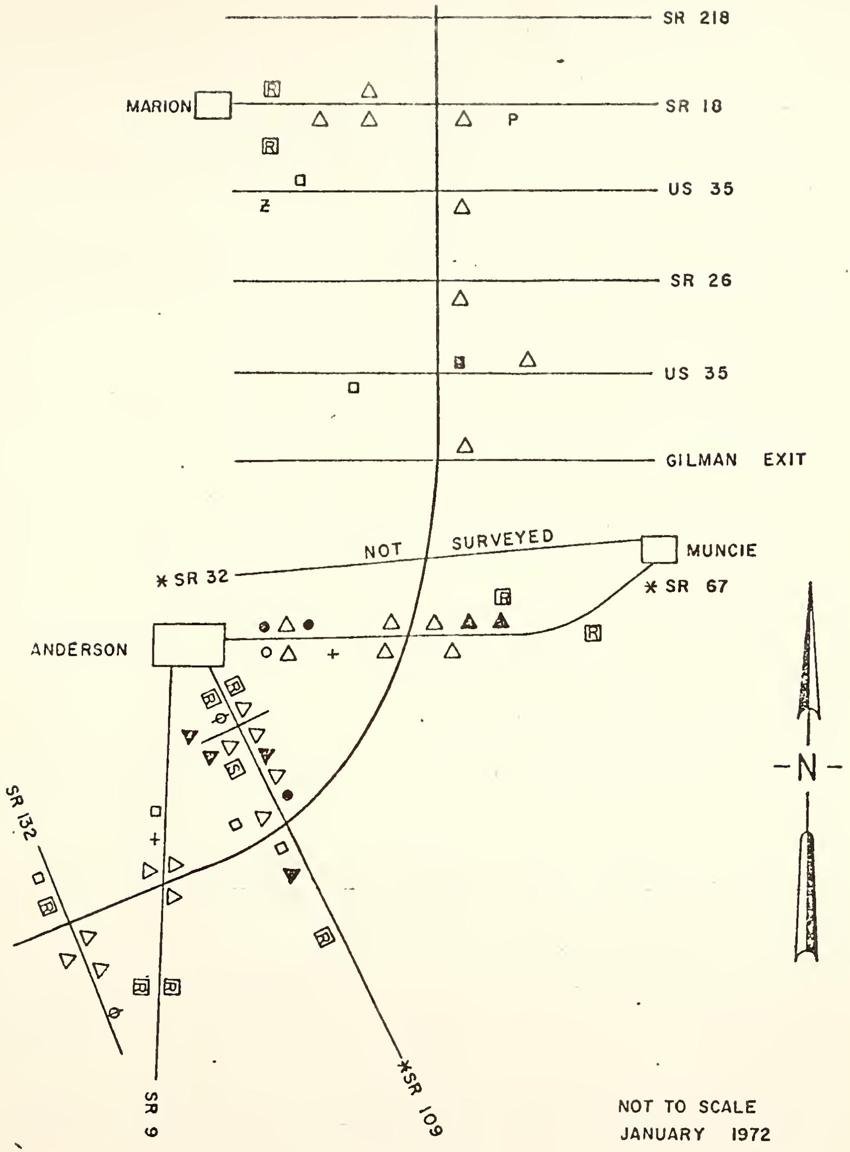


FIGURE 6. INTERSTATE 69 INTERCHANGE DEVELOPMENT CONTINUED

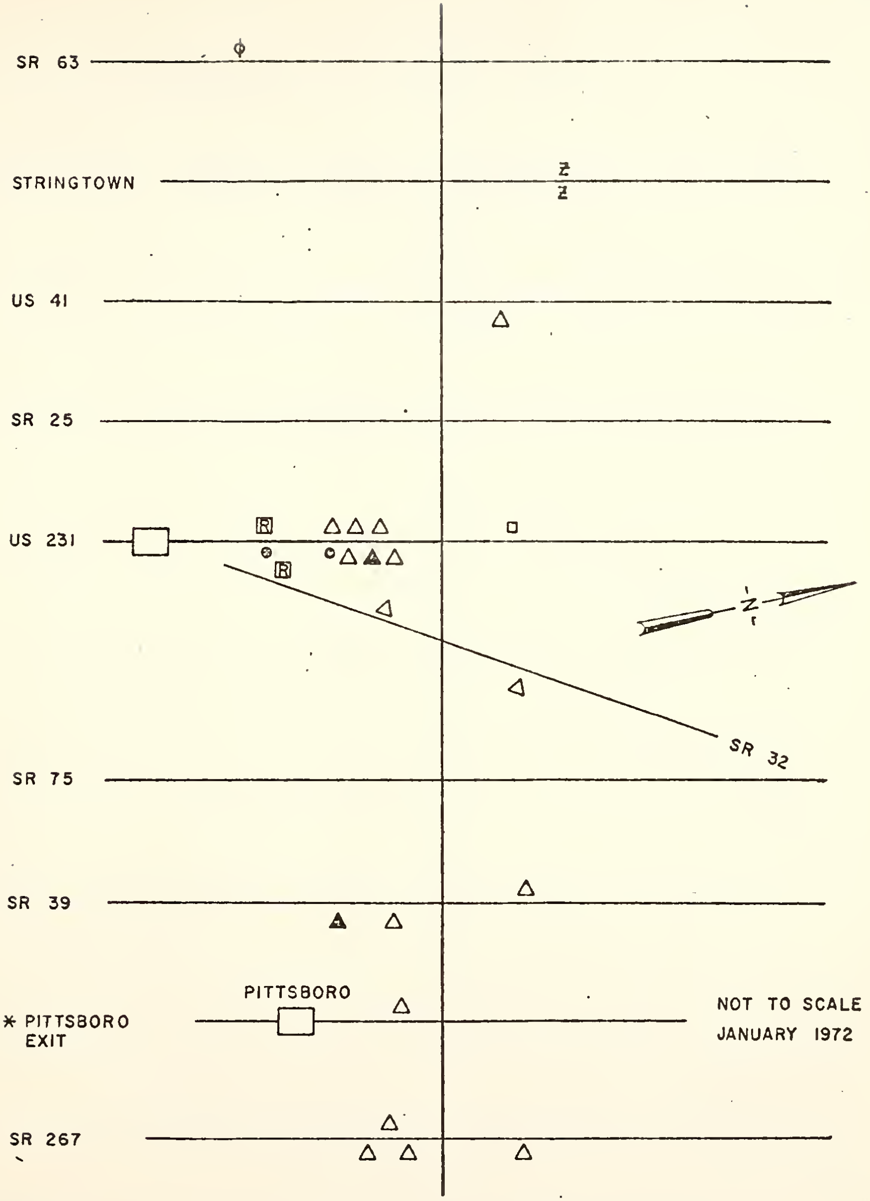


FIGURE 7. INTERSTATE 74 INTERCHANGE DEVELOPMENT WEST OF INDIANAPOLIS

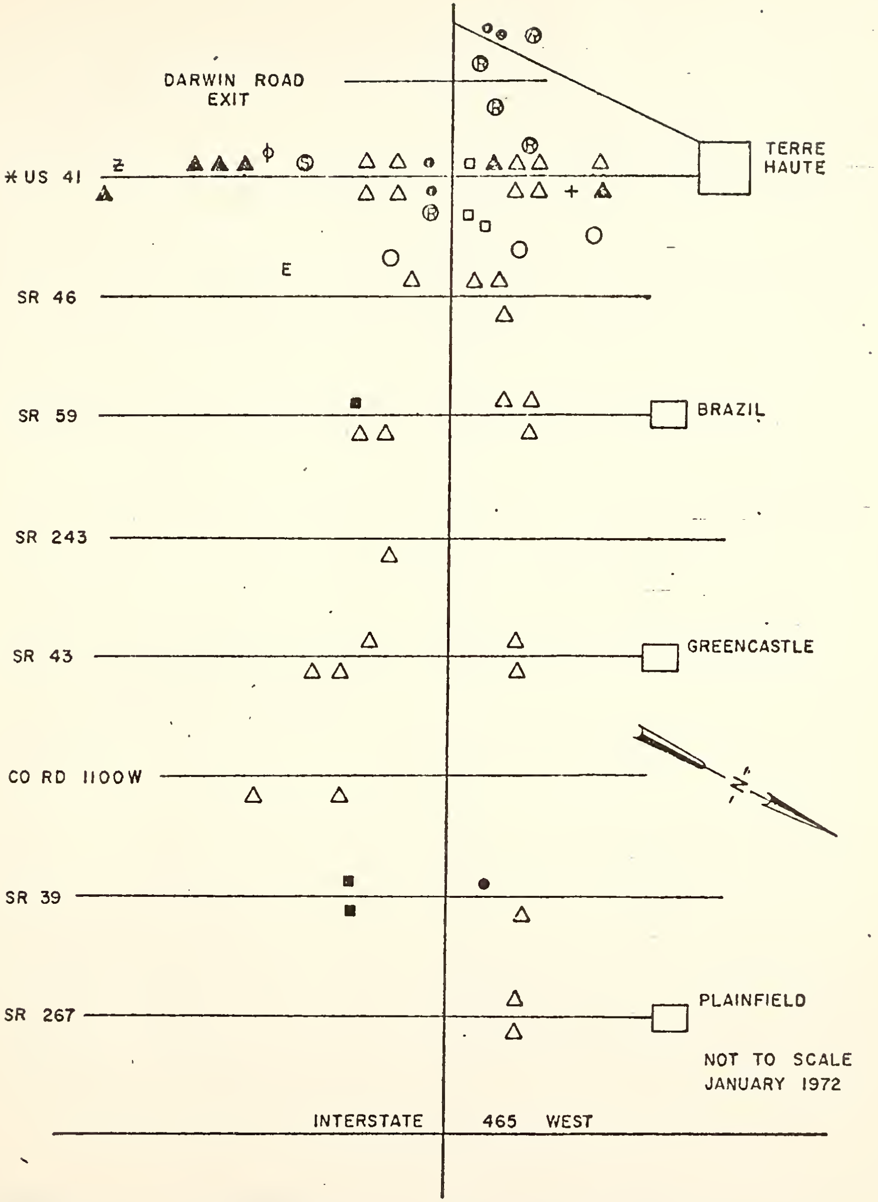


FIGURE 8. INTERSTATE 70 INTERCHANGE
DEVELOPMENT WEST OF INDIANAPOLIS

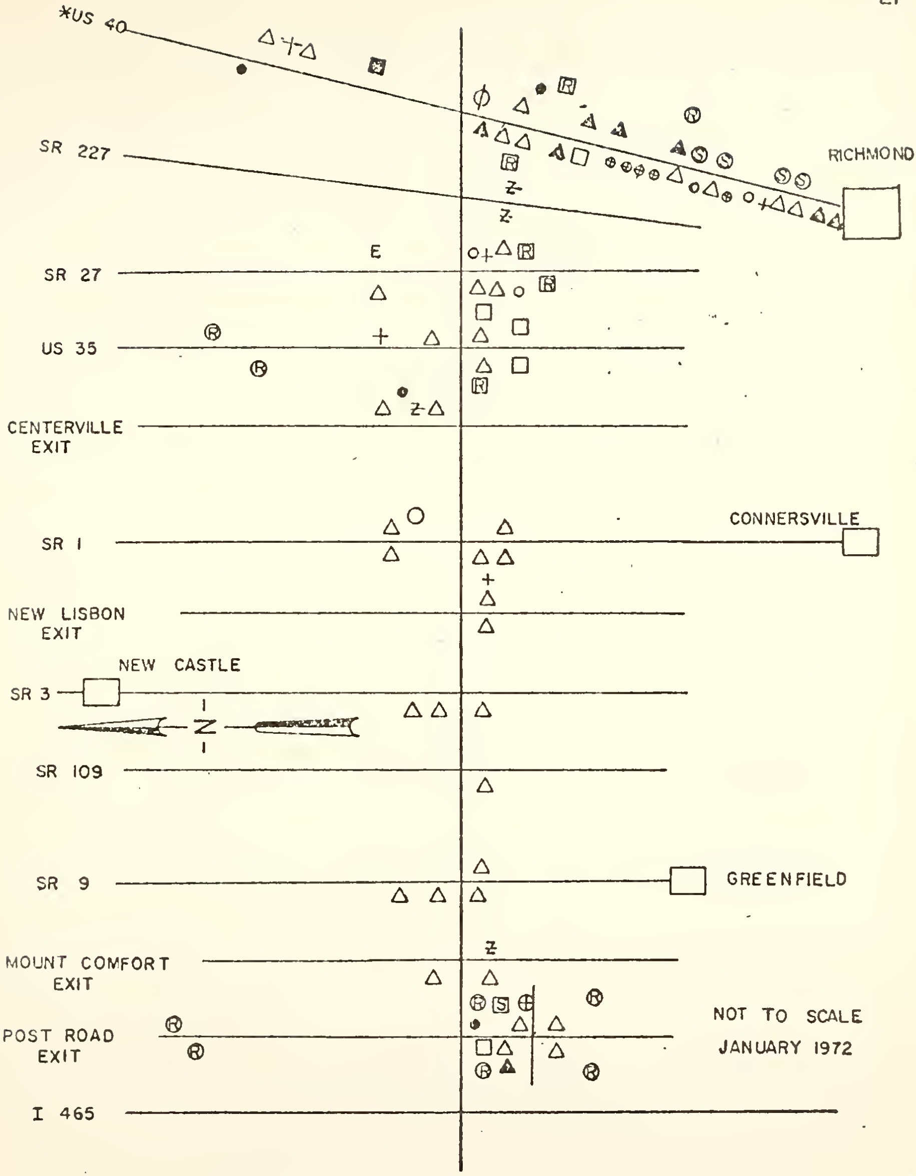


FIGURE 9. INTERSTATE 70 INTERCHANGE DEVELOPMENT EAST OF INDIANAPOLIS

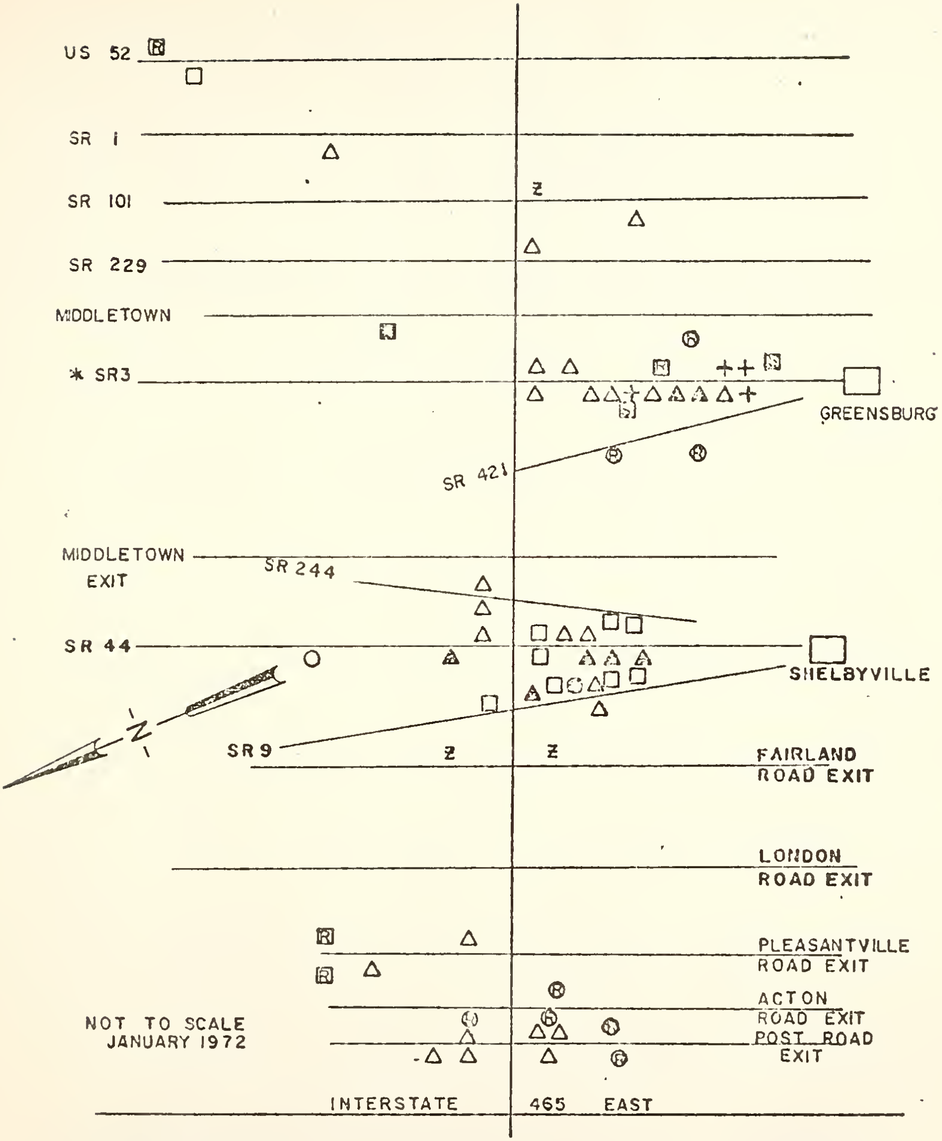


FIGURE 10. INTERSTATE 74 INTERCHANGE DEVELOPMENT EAST OF INDIANAPOLIS

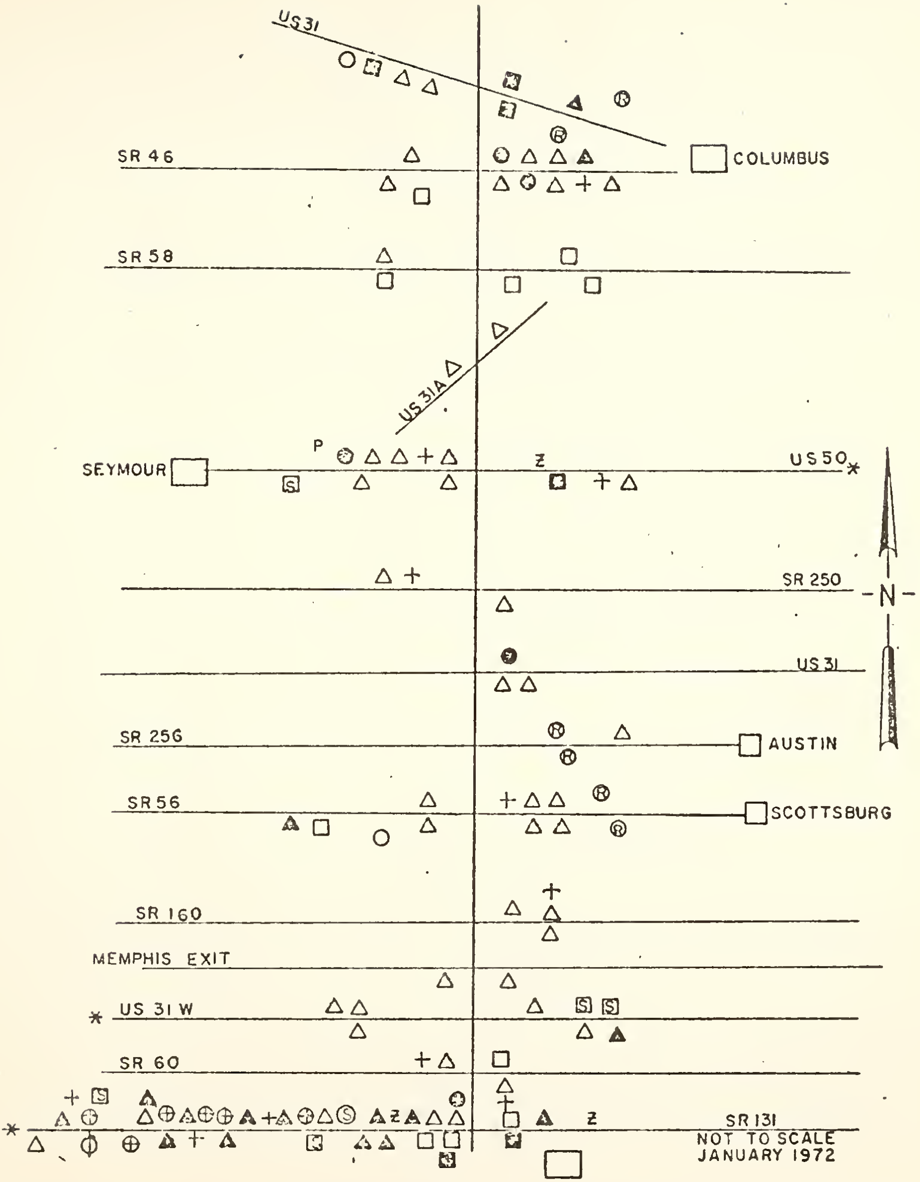


FIGURE II. INTERSTATE 65 INTERCHANGE DEVELOPMENT SOUTH OF INDIANAPOLIS

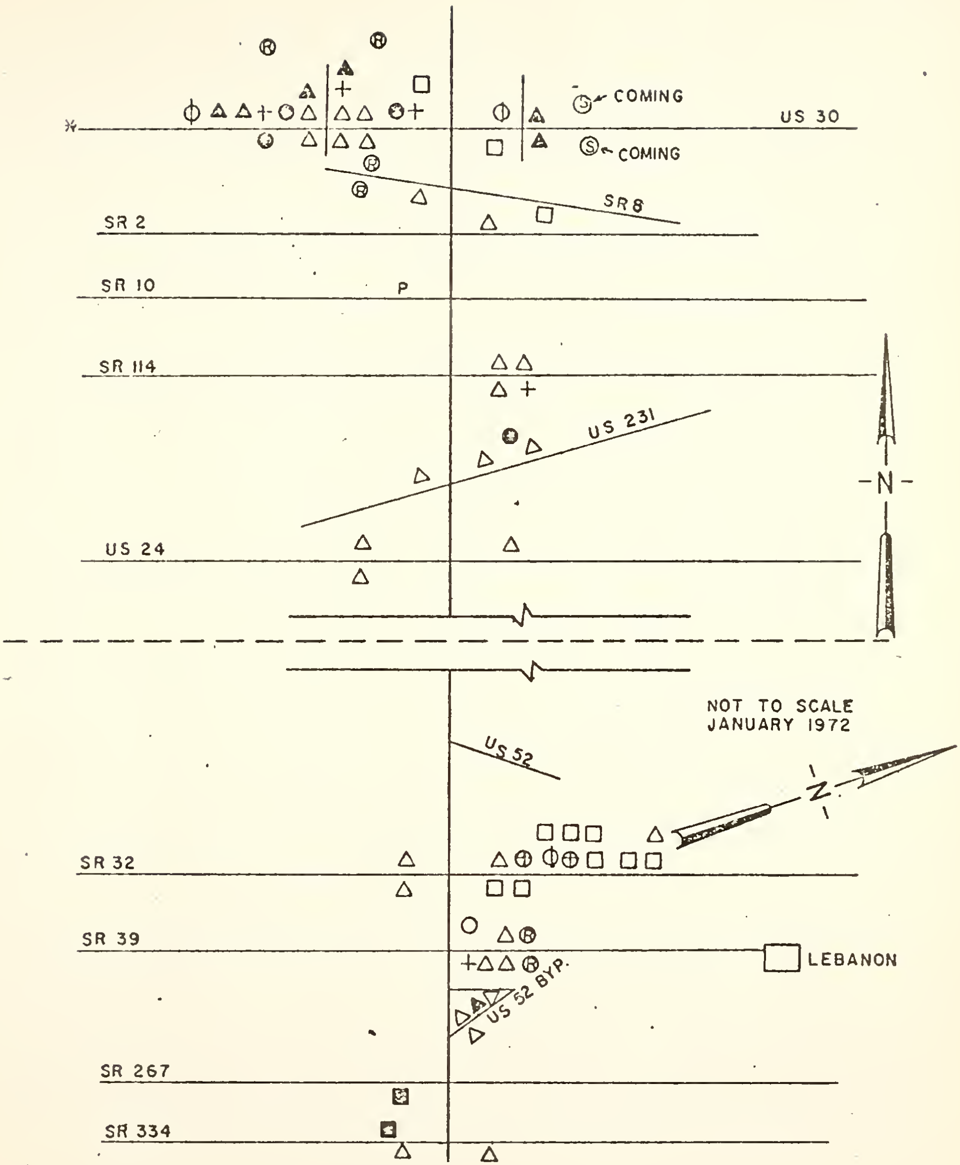


FIGURE 12. INTERSTATE 65 INTERCHANGE DEVELOPMENT NORTH OF INDIANAPOLIS

Volumes on the crossroute, ramps, and Interstate were all collected from volume maps or field sheets available from the Traffic Planning Division of the Indiana State Highway Commission. Where complete volumes for a given interchange were not found on the statewide 1952, 1958, 1962, 1966, and 1969 volume maps, supplemental strip maps, isolated counts, or interchange volume maps were utilized; and, state conversion factors to adjust to approximate ADTs were used as listed in Appendix D.

Populations of urban areas over 1000 were obtained from 1950, 1960, and 1970 Census Reports of Indiana.

Travel distances were taken as measured or as recorded from the 1971-1972 Indiana State Highway System road map (Scale; 1"=5miles). Distances were measured from interchange to interchange, interchange to urban centers, and interchange to old parallel State highway routes. The data manipulation section will describe the conversion of travel distances to travel times.

Interchange type was established from ISHC design drawings and checked during the field survey.

Interchange and Interstate roadway section ages were taken from maintenance records establishing maintenance responsibilities for new Interstate roadway sections. This source provided the best estimate of the interchange opening dates since no complete tabulation of opening dates or of construction dates were available in the Construction Division of the Indiana State Highway Commission.

Accident tabulations on the statewide Accident Spot Maps were considered unreliable for meaningful aggregate traffic hazard evaluation. Accidents were also too difficult to obtain in detail from the Indiana State Highway Patrol files or from original accident records throughout the state within the reasonable scope of this project and so unfortunately were excluded from the study.

Data Manipulation

Before any data analysis was undertaken, the raw data as collected was punched onto computer cards. The coding system shown in Appendix C was designed for the short term purposes of this research as well as for more diverse demands of future research.

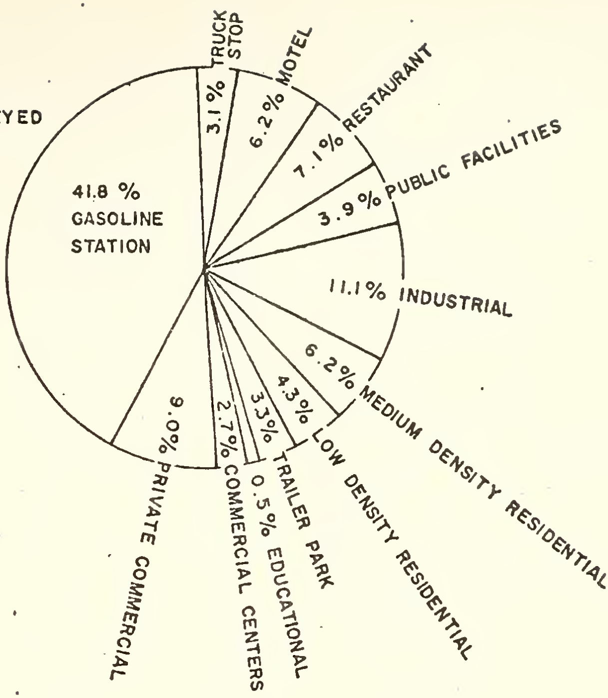
Each of the variables required some data summarization and data transformations prior to modeling. Summarizations and transformations of the development were used to determine homogeneous classes of data, to approximate similar levels of aggregation for all variables, and to approximate a common base measure for each variable.

Figures 13 and 14 show percentages of existing land development by land use type on a one establishment one unit of development measure criteria.

For all 102 interchanges studied, road user services, including gasoline stations, truck stops, motels, and restaurants, represent 58.2 percent of existing establishments. This percentage increases to 76.9% for rural interchanges, is 58.7% for suburban interchange area systems, and decreases to 46.5% for urban fringe interchanges. Private commercial and shopping centers constitute 11.7% of development for all interchanges, 1.7% in the rural areas, in 12.3% in the suburban areas, and 19.2% in the urban fringe areas; industrial 11.1% in all areas, 5.7% in rural areas, 12.2% in suburban areas, and 12.6% in urban fringe areas; and as a last major development category combined residential is found as a land use in 10.5% of all interchange areas, 8.0% of rural interchange areas, 11.6% of suburban interchange areas, and 14.6% of urban fringe interchange areas. These comparisons reflect the interdependence of land uses and the importance of complimentary market areas. For instance, the noticeable increase in private commercial establishments with increased urban influence reflects the importance of a superimposed total of Interstate travelers, crossroute travelers, and local convenience travelers in interchange location decisions of private enterprise.

A classification of rural, suburban, and urban fringe interchanges by geometric interchange design type resulted in the tabulation of establishments as shown in Summary Table 1.

ALL 102 INTERSTATE INTERCHANGES SURVEYED WITH 578 UNITS OF DEVELOPMENT



74 RURAL INTERSTATE INTERCHANGES WITH 180 UNITS OF DEVELOPMENT

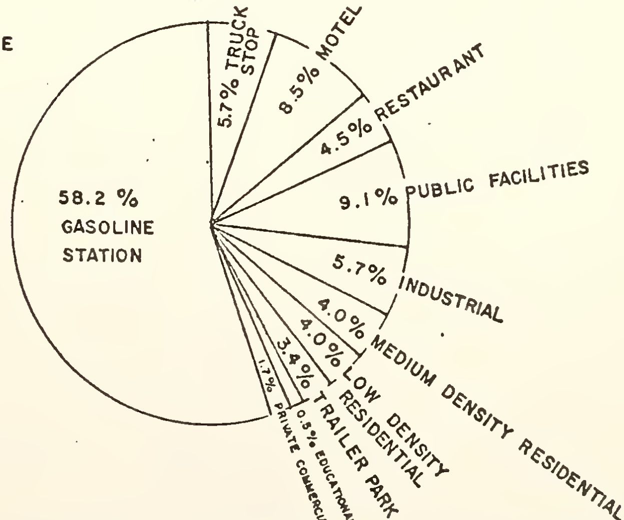


FIGURE 13. INTERSTATE INTERCHANGE DEVELOPMENT BY TYPE OF INTERCHANGE AND BY PERCENTAGE OF LAND USE TYPE

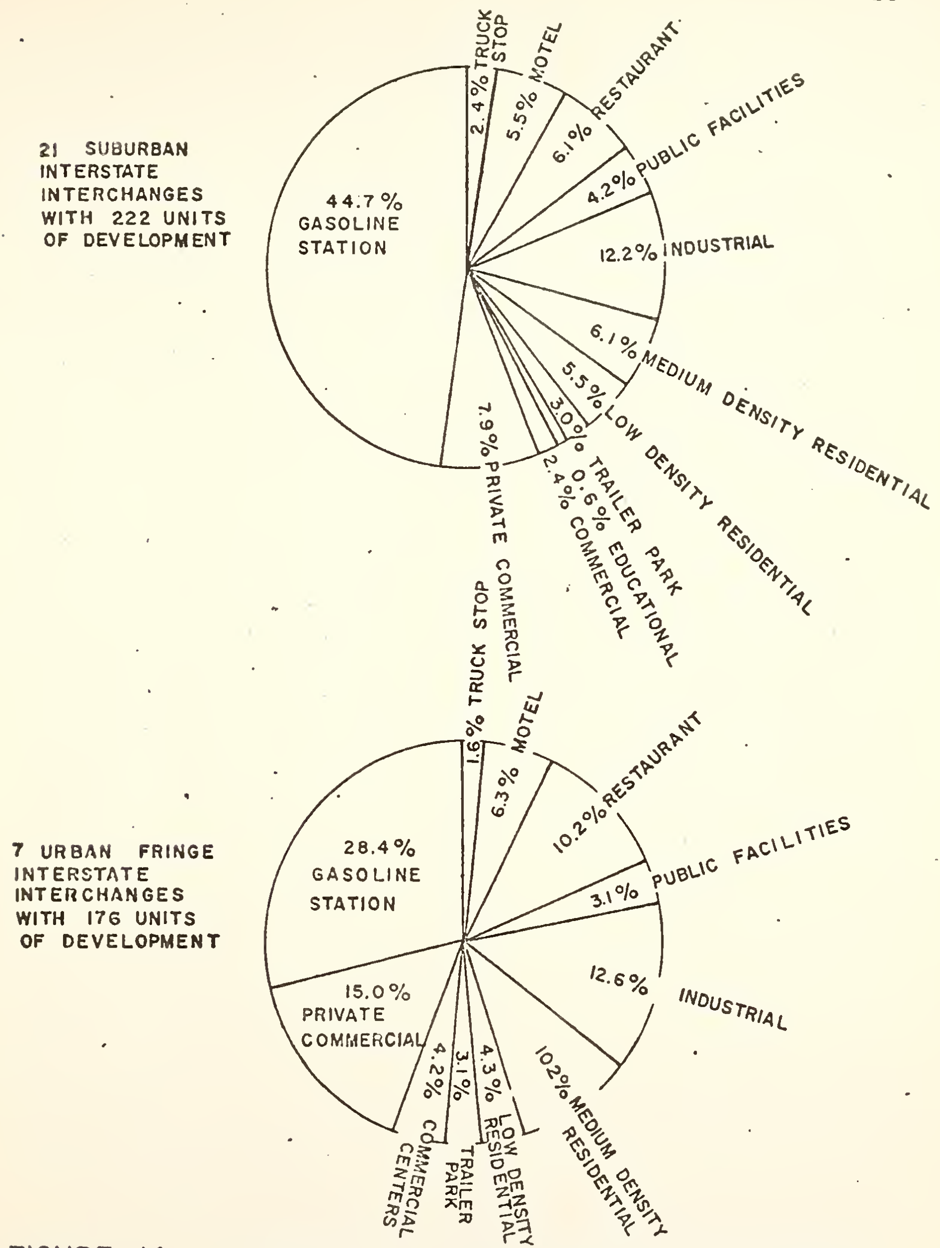


FIGURE 14. INTERSTATE INTERCHANGE DEVELOPMENT BY TYPE OF INTERCHANGE AND BY PERCENTAGE OF LAND USE TYPE

These breakdowns in Figures 13 and 14 and Table 1 were useful to determine that diamond interchanges of the rural type constitute the only homogenous class with enough road user land use observations to warrant upcoming modeling consideration.

While not within the scope of this research, it was felt that similar percentage summaries based on future expansive multi-state inventories would be very useful in establishing probabilities for parcel by parcel estimation of future land uses after being initially categorized by factors such as interchange characteristics and interchange design type.

As may be noted several volume counts were collected over time for crossroutes, ramps, and Interstate routes. There were several reasons for this. First, the time series data enabled us to make a fair estimate of 1971 volumes where they were not counted or not available for 1971. In projecting volumes, if only one count was available for crossroute, ramp, or Interstate link, the 1971 volume was estimated as a four percent (17) increase in volume per year from the time of the single count. Where two counts were available a straight line projection to 1971 was used. For three or more counts over time, the rates of change between successive counts were determined, were averaged, and this average rate when multiplied by the time lapse in years since the most recent count would yield the absolute change in that count resulting in an acceptable estimate of 1971 volume of the link in question. Secondly, time series data makes short term predictive applications of the model possible by making projection of these potential independent variables very easy. But, far better than this projection of a deterministic model, future research, after a good model is built for 1971, could formulate models with identical variables for, as an example, three year intervals prior to 1971 to do a pseudo-dynamic analysis of change in parameters and to identify a mathematical expression of causal relationships over time.

Of the raw data collected the other major transformation prior to modeling was in converting minimum travel paths from distances to times. The minimum travel path in time was determined manually in distances broken down by freeway, four lane rural, two lane rural, and

TABLE I. QUADRANTS WITH DEVELOPMENT BY NUMBER AND LOCATION

TRUCK STOP		MOTEL		RESTAURANT		PUBLIC FACILITIES		INDUSTRIAL		COMBINED RESIDENTIAL		TRAILER PARK		EDUCATIONAL		COMMERCIAL CENTER		PRIVATE COMMERCIAL		GASOLINE	SERVICE	QUAD. AVAILABLE	INTERCHANGE	TYPE
O	I	O	I	O	I	O	I	O	I	O	I	O	I	O	I	O	I	O	I	O	I	QUAD.		
6	4	3	4	3	4	5	8	4	3	5	6	1	4	0	2	0	0	2	0	34	49	248	DIAMOND	RURAL
0	0	2	0	0	0	1	1	1	0	1	2	0	0	0	0	0	0	0	0	2	2	20	OTHER	
0	0	4	2	4	2	2	2	5	2	3	3	4	0	0	0	0	1	8	0	14	14	34	DIAMOND	SUBURBAN
2	2	1	1	1	4	1	0	1	2	4	4	1	0	0	0	1	1	1	1	5	6	24	CLOVERLEAF	
0	0	0	1	1	0	0	0	2	0	3	3	1	0	0	1	1	1	1	1	5	3	15	OTHER	
0	1	4	4	2	5	2	0	2	4	6	5	2	2	0	0	3	2	2	3	5	7	16	CLOVERLEAF	URBAN FRINGE
1	1	2	4	4	3	1	2	5	2	5	6	3	2	1	0	3	2	4	5	5	6	16	OTHER	
9	8	16	16	15	18	12	13	20	13	27	26	12	8	1	3	8	7	18	10	70	87		TOTAL QUADRANTS OCCUPIED	
2.1	2.1	4.2	4.2	4.0	4.8	3.2	3.4	5.3	3.4	7.2	6.9	3.2	2.1	0.2	08	2.1	1.8	4.8	2.6	18.7	23.3	% OF TOTAL QUADRANTS OCCUPIED		

NOTE: COMPLETELY VACANT OR AGRICULTURAL QUADRANT = 169

I	INTERSTATE O
CROSSROUTE O	I

I — FIRST QUADRANT ACCESSIBLE FROM INTERSTATE OFF RAMP CROSSROUTE TERMINALS WITHOUT CROSSING CROSSROUTE CENTERLINE

O — ALL OTHER QUADRANTS

four lane urban mileages. These distances were converted to minimum time by using the average speed of travel considered representative (27) for the differing roadways and corresponding conversion factors as listed in Table 2.

TABLE 2

TRAVEL DISTANCE TO TRAVEL TIME CONVERSION FACTORS

	SPEED	CONVERSION FACTOR
INTERSTATE	60MPH	1.00
4-LANE RURAL	50MPH	1.20
2-LANE RURAL	45MPH	1.33
4-LANE URBAN	30MPH	2.00

CHAPTER V
DATA ANALYSIS

Variable Development

Dependent or Response Variable

The response variable modeled is the magnitude of road user developments at an interchange. Two alternative models were developed. One model considers each road user establishment as one unit of development. For instance, an interchange with two gasoline service stations and another interchange with two truck stops would each rate as two units of development.

In the other model a weight was applied to each development in recognition of the fact that each land use activity generates varying amounts of traveler conflicts at crossroute access points. The following subjective weights consider these different anticipated generation rates by land use type but do not reflect finer bases of sophistication which would result from an extensive traffic count by land use type study.

TABLE 3
LAND USE WEIGHTS

WEIGHT	LAND USE (See Appendix C)
1	Service Station
2	Service Station + Restaurant
$1\frac{1}{2}$	Motel (Large Chain)
$\frac{1}{2}$	Motel (Small Chain)
1	Restaurant
4	Truck Stop (Auto-Food-Lodging-Truck Service)
3	Neighborhood Shopping Center
6	Regional Shopping Center
$1\frac{1}{2}$	Service Station + Short Order

Crossroute volume, ramp volume, Interstate volume, interchange age, and Interstate age were all used in the form resulting from initial data manipulation as described in the preceeding chapter.

A population index was developed from the populations and minimum travel time from the interchange to the population centers. The premise is that an index composed of the summation of population divided by the accessibility within a given corridor of travel. For example, interchange 1 in corridor A would have a population index $I_1 = \sum_{i=1}^{n} \frac{\text{pop } i}{(\text{dist } 1\text{-}i)^m}$ where I_1 is the index, n is the number of population centers with population greater than 1000 in corridor A, pop i is the population of center i in corridor A, and $(\text{dist } 1\text{-}i)^m$ is the distance in minimum travel time from interchange population center i raised to an exponent m to be calibrated. The corridors for the different Interstate routes radiating away from Indianapolis extend twenty miles at the most to either side of the Interstate. Where two Interstates' corridors would overlap, as is the case when nearing Indianapolis, the area between Interstate routes was bisected to establish a breakpoint for one corridor from another. For example, US 52 was roughly the boundary for the corridors of I-70 and I-74 just East of Indianapolis until Rushville where the twenty mile limit takes effect.

The exponent m was calibrated by plotting population indexes based on distance exponent values of m= 1.0,1.1,1.2,1.3,1.4,1.5,1.6,1.7,1.8 1.9,2.0,2.3,2.6,2.9,3.2,3.5,3.8,4.1,4.7,5.0 in the denominator used once each with log 10 pop i, square root pop i, and pop i in the numerator for each interchange versus the weighted development at that interchange. The plots showed no distinct linear or curvilinear relationships although the graph with log 10 pop i $/(\text{dist } 1\text{-}i)^1$ seemed to be the graph with least disparity from a linear plot and so $I_1 = \sum_{i=1}^{n} \log 10 \text{ pop } i/(\text{dist } 1\text{-}i)^1$ was the population index used for each interchange.

A variable labeled economic shift index was also developed. The data used to develop this index was based on volumes on routes parallel to the Interstate, bisecting the crossroute, and within the Interstate corridor as delimited for the population indexes above. For

each interchange, volumes on both sides of the crossroute were collected and averaged for each parallel route. The average parallel volumes recorded before interchange opening were then projected to 1969 for each parallel route. This volume projection was estimated by using average rates of volume change or a 4% increase where only one year's volume record was available, much as the crossroute, ramp, and Interstate volumes were projected earlier. The parallel route projection was then compared to the actual count available on the ISHC 1969 statewide volume count map. The difference once determined was divided by the parallel route's distance from the interchange. The net result for each interchange was an Economic Shift Index $= \sum_{i=1}^{n}$ Diverted Volume i / Distance to Parallel Route i, where n = number of parallel routes for a given interchange.

Aggregate base variables were also developed. Populations within ten, within twenty, and within thirty minutes of each interchange were compiled as three separate potential independent variables. However since within ten minute population was a component of within twenty minute population, and both within ten minute population and within twenty minute population were components of within thirty minute population, only one of the three variables would be allowed to enter the final model because of their high correlation with one another.

The last base variables considered were labeled weighted competition and unweighted competition. The weighted competition is simply the sum of weighted development for interchanges within fifteen miles of the interchange system being considered. Fifteen miles was chosen because it was subjectively decided that a person would use an interchange for road service within thirty miles of the time he establishes his need. The unweighted competition variable was based on unweighted development totals for interchanges within fifteen miles of the interchange system being considered. The weighted and unweighted development variables were used only with the weighted and unweighted response variable models respectively and not intermixed to avoid misleading results.

A summarization of the base variables used for modeling and described above is as follows:

Dependent	Through 1971 Weighted Development
Independent	1971 Crossroute Volume
Independent	1971 Off Ramp Volume
Independent	1971 Interstate Volume
Independent	1970 Population Index
Independent	1970 Population Within 10 Miles
Independent	1970 Population Within 20 Miles
Independent	1970 Weighted Development Competition
Independent	1970 Population Within 30 Miles
Independent	Interchange Age
Independent	Interstate Route Age
Dependent	Unweighted Development
Independent	Unweighted Development Competition
Independent	Economic Shift Index

Assumptions For The Statistical Method

Multiple linear regression was the method of analysis used to analyze land development in interchange areas. Some assumptions for multiple linear regression are that the independent variables are additive and uncorrelated with each other while being highly correlated in a linear fashion with the dependent variable, that there is homogeneity of variance of the dependent variable for different additive effects of independent variables, that the distribution of the error term is normal with mean zero, and that the independent variables are easily collected, easily forecasted, and causally related to the dependent variable.

Plots of each independent variable versus the dependent weighted variable were the basis for assuming a linear relationship. Because of the scattering of many of these plots, transformations and interactions of the basic variables were considered in analysis. Plotting and crossclassification and not a formal statistical test were used as a determination of homogeneity since a crossclassification of the dependent

variable versus an independent variable contains an inordinate amount of empty cells which it was felt would distort the value of a structured statistical test. The independent variables used in the best model are easily collected with appropriate manpower, are forecastable, and are all reasonably hypothesized through a conceptual basis of being causally related to the dependent weighted variable. Causality, put simply, means an independent variable change produces a change in the dependent variable without an intermediate variable in the chain. Normality was still assumed in spite of the discouraging plot in Appendix E.

Statistical Measures

In modeling these variables discussed earlier, the BMD2R (24) package program was used for multiple stepwise regression analysis. An excellent discussion of statistical measures used in multiple stepwise regression can be found in Chapter Four of Joint Highway Research Project Number 37 (10). However, to summarize and supplement that work the statistical terms used frequently in the model result tables will now be described.

BMD2R will yield an initial correlation cofficient matrix of each variable entered to every other variable entered. While the correlation between the response variable and each independent variable is most important, the correlations between independent variables are also of interest in avoiding, where possible, collinearity of the independent variables. The initial correlation matrix is computed between each variable by using the equation

$$r_{XY} = \sum_{i=1}^{n} (X_i - \bar{X})(Y_i - \bar{Y}) \Big/ \left(\left(\sum_{i=1}^{n} (X_i - \bar{X})^2\right)^{1/2} * \left(\sum_{i=1}^{n} (Y_i - \bar{Y})^2\right)^{1/2} \right)$$

The independent variable with the highest correlation with the response variable will enter as it will yield the highest R-squared. R-squared is defined as the Sum Of The Squares due to regression divided by the Total Sum of Squares, corrected for the mean. The stepwise program performs a partial F-Test on each of the variables in the model at each step of the program to determine whether the highest partially correlated independent variable not yet in the model should enter or whether after a new variable enters others already in the

model should be removed. The F-Ratio determined by appropriate quotients of the Mean Sum of The Squares is compared to a critical F whose value is a given in statistical F tables for differing degrees of freedom for the numerator and denominator. (19)

The standard error of estimate is a measure of the spread of the observed data points about the regression line.

With this synopsis of statistical measures, a discussion of model development will follow.

Of the one hundred two interchanges surveyed a complete data set of 13 base variables, excluding the Economic Shift Index, was available for 82 interchanges. A multiple stepwise regression was run for these 82 cases. The thirteen base variables were entered along with the transformations, such as log 10, square root, and square which seemed appropriate after plotting the dependent variable versus each base independent variable and interaction terms of the same base variables and transformations which seemed logical. The correlation matrix of 31 variables indicated that ramp volume and crossroute volume each in its nontransformed and noninteraction base state had the highest correlation with both the unweighted and weighted dependent variables. The results of the best weighted and unweighted models at $F_{.25} = 1.35$ (a 25% probability that we would observe a critical F-Value exceeding 1.35) for 82 cases are as follows:

TABLE 4

MODEL 1 RESULTS

AFTER STEP NUMBER	VARIABLE ENTERED	R	MULTIPLE R-SQUARED	F-VALUE TO ENTER OR REMOVE
1	X3 Crossroute	.6491	.4214	57.52
2	X7 Weighted Competition	.6677	.4458	3.44
3	X10 Route Age	.6774	.4589	1.86
4	X2 Ramp Volume	.6852	.4695	1.51
5	X6 Population within 20Mi.	.6943	.4821	1.81
6	X11 Interstate Volume	.7082	.5016	2.88
7	X4 Population Index	.7193	.5174	2.39

Standard Error of the Estimate = 26.45

$$\begin{aligned}\text{Weighted Development Index }(10) = {}& -10.66763 + .03943X_2(10)^{-1} \\ & +.04544X_3(10)^{-1} + .23058X_4(10)^{-1} \\ & -.00615X_6(10)^{-2} - .07147X_7(10) \\ & +1.63802X_{10} + .20260X_{11}(10)^{-2}\end{aligned}$$

TABLE 5

MODEL 2 RESULTS

AFTER STEP NUMBER	VARIABLE ENTERED	R	MULTIPLE R-SQUARED	F-VALUE TO ENTER OR REMOVE
1	X3 Crossroute Volume	.6332	.4010	44.59
2	X13 Unweighted Competition	.6410	.4109	2.75
3	X4 Population Index	.6533	.4268	1.37
4	X11 Interstate Volume	.6604	.4362	2.46
5	X6 Population Within 20Mi.	.6680	.4463	3.57

Standard Error of the Estimate = 20.83

$$\text{Unwieghted Development Index } (10) = -2.32037 + .04279X_3(10)^{-1} -.05259X_{13}(10)^{-1} + .19978X_4(10)^{-1} +.09988X_{11}(10)^{-2} - .05259X_6(10)^{-2}$$

The R-Squared is only .4463 and so the weighting of development seems to add to the model's fit and is the only alternative considered hereafter.

At this juncture, with such a low R-Squared and with the residual plot of the dependent variable being somewhat linear, two changes were made. First, the interchanges of the urban and suburban classes were removed from the 82 cases leaving 63 more normal but with less variation and then the Economic Shift Index base independent variable was added necessitating removal of 11 more data points leaving 52. As noted, this class of interchanges remaining was felt to closer approximate the linear regression assumptions. The results of the best model with $F_{.05} = 3.98$ at this disaggregated level is:

TABLE 6

FINAL MODEL RESULTS

AFTER STEP	VARIABLE ENTERED	R	R^2	F-VALUE
1	X2 Ramp Volume	.5541	.3070	42.19
2	X6 Population Within Twenty Miles	.6032	.3639	10.87
4	X9 Interchange Age	.6765	.4576	8.04
6	X14 Economic Index	.7167	.5136	24.38
9	X16 Economic Index/ Population Index	.7739	.5989	17.08

Standard Error of Estimate = 13.87

$$
\begin{aligned}
\text{Weighted Development } (10) = {} & 20.16 + 1.18\ (\text{Ramp Volume})\ (10)^{-2} \\
& -.05897\ (\text{Population Within Twenty Miles})\ (10)^{-3} \\
& -2.49069\ (\text{Interchange Age}) \\
& +.84518\ (\text{Economic Index})\ (10)^{-2} \\
& -25.18036\ (\text{Economic Index})\ (10)^{-2}/(\text{Population Index})\ (10)
\end{aligned}
$$

Although an aggregate land use development model with R-Squared equal to .5989 might ordinarily be considered satisfactory, because of questionable parameters and two highly theoretical variable indexes, the land use development variable and the above model should be further refined before being used for specific land use development predictions. However, the above model is the best model that can be developed with the aggregate data collected without adding extensive additional data collections of trip generation by land use type to refine development weights and to identify other causal independent variables. In addition, the normality plot of the residuals in Appendix E leads to the conclusion that this model is still lacking some as yet undiscovered linear factor or linear interaction.

CHAPTER VI
INTERCHANGE CASE STUDIES

The following case studies will progressively subjectively show, where the regression modeling of the past chapter objectively cannot, that interchange area land development is inevitable, sometimes very explosive, and should be carefully planned for, especially in suburban interchange areas where growth is active and planning could still be useful.

To be comprehensive this discussion will begin with the least critical rural interchange classification. In these areas there presently exist no immediate land use dangers to the traffic capacity of the interchange ramps and of the crossroutes. Review of development plans at the District and at the State Highway Commission levels have successfully kept driveway cuts for roadside development a safe distance (400') away from ramp terminals.

It was found that many establishments in these rural areas desire the visibility and the related free advertising offered by plots adjacent to the Interstate interchange right of ways. Nevertheless, through their own initiative, restricted by access rights a distance along the crossroute frontage, or in cooperation with traffic permit and planning review boards they have located their crossroute access points safely out of conflict with ramp terminals.

Neither ramp congestion associated with crossroute blockage and with ramp terminal traffic signal controls nor ramp safety problems associated with nearness and conflict of first crossroute driveway or roadway access after a ramp terminal are problems at this time. Second and additional driveway or roadway access points, their spacing, and frequency along the crossroute as pertinent to crossroute congestion, delay, and safety are not presently problems either.

However, to let the next few years pass without active interchange area planning and enforcement in implementing controls could be disasterous when comparing the small required expenditure for land use planning to the potential loss of existing interchange structural investments as well as lost interim interchange area land investment.

The situation is quickly approaching or has already approached a critical state in suburban interchange areas without adequate long range interchange area planning. At the interchanges the familiar commercial strips, existent on major urban arterials and on urban bypasses and often correlated with past and present hazard-through-too-frequent-direct-access-to abutting-land, is found growing along suburban crossroutes leading to nearby urban centers. Surburban interchange areas chosen for illustration and brief commentary are the junctions of Interstate 65 and State Route 46, of Interstate 65 and U.S. Route 50, of Interstate 70 and U.S. Route 231, of Interstate 74 and State Route 44, of Interstate 69 and State Route 8, and of Interstate 74 and State Route 3. The order of presentation is deliberately planned to roughly start with the least developed interchange area in an effort to subjectively establish a progression from one extreme of development to the other extreme.

CASE I: Interchange of Interstate 65 and State Route 46

This interchange area is in what could be considered an early stage of strip development extending out from Columbus west to the Interstate 65. The existing initial development is concentrated with frequent direct crossroute access to predominantly road user services immediately adjacent to Interstate right of way boundaries in the Northeast and Southeast quadrants. However, as land develops in the present gap between urban Columbus and the Interstate and as the Northwest and Southwest quadrants begin to develop more densely than present scattered residential plots amid agricultural fields, the already heavy volume on dual lane State Route 46 may become significantly congested during peak travel periods. With Cummins Diesel, a major employer in Columbus relocating at the next Interchange south on Interstate 65 and with the many recreational opportunities of neighboring Brown County to the West, Columbus' growth in the near future to the West and to the South should at least equal recent growth to the North and to the East.

Growth at this interchange has proceeded at a steady rate since its opening in 1962. An anticipated crosssection of four moving lanes for SR46 was wisely planned for its grade separated crossing with Interstate 65; but, a plan must provide for proper setback and right of way purchase along the crossroute between the Interstate and Columbus.

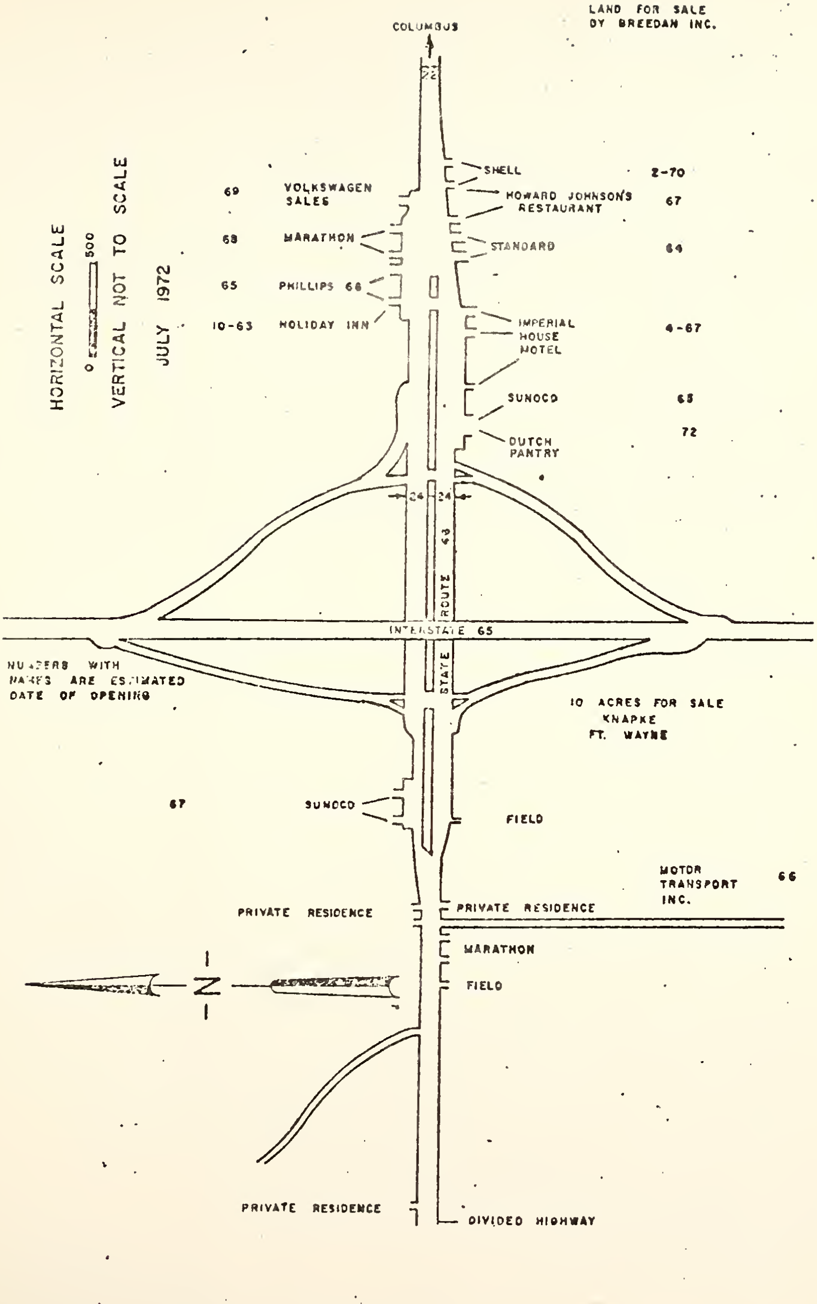


FIGURE 15. STATE ROUTE 46 & INTERSTATE 65 INTERCHANGE

This interchange, open since 1961, did not develop at first with a drive-in theater, restaurant, and a gasoline station there much before the Interstate, constituting the only investment activity until 1965. 1965 marked the beginning of extensive development up to the present time. Road services located during the 1965 through 1968 period, with surburban offices, a church, and a neighborhood shopping center related to the expansion of Seymour toward the Interstate being the uses developing since 1968.

In this case a four lane crossroute highway west of the Interstate into Seymour, designed with limited median crossing points, displays intelligent interchange area planning. However, many closely spaced driveways shown in the Northwest quadrant of the interchange along U.S. Route 50 on Figure 16 creates a potentially hazardous segment of roadway near a high speed freeway exit.

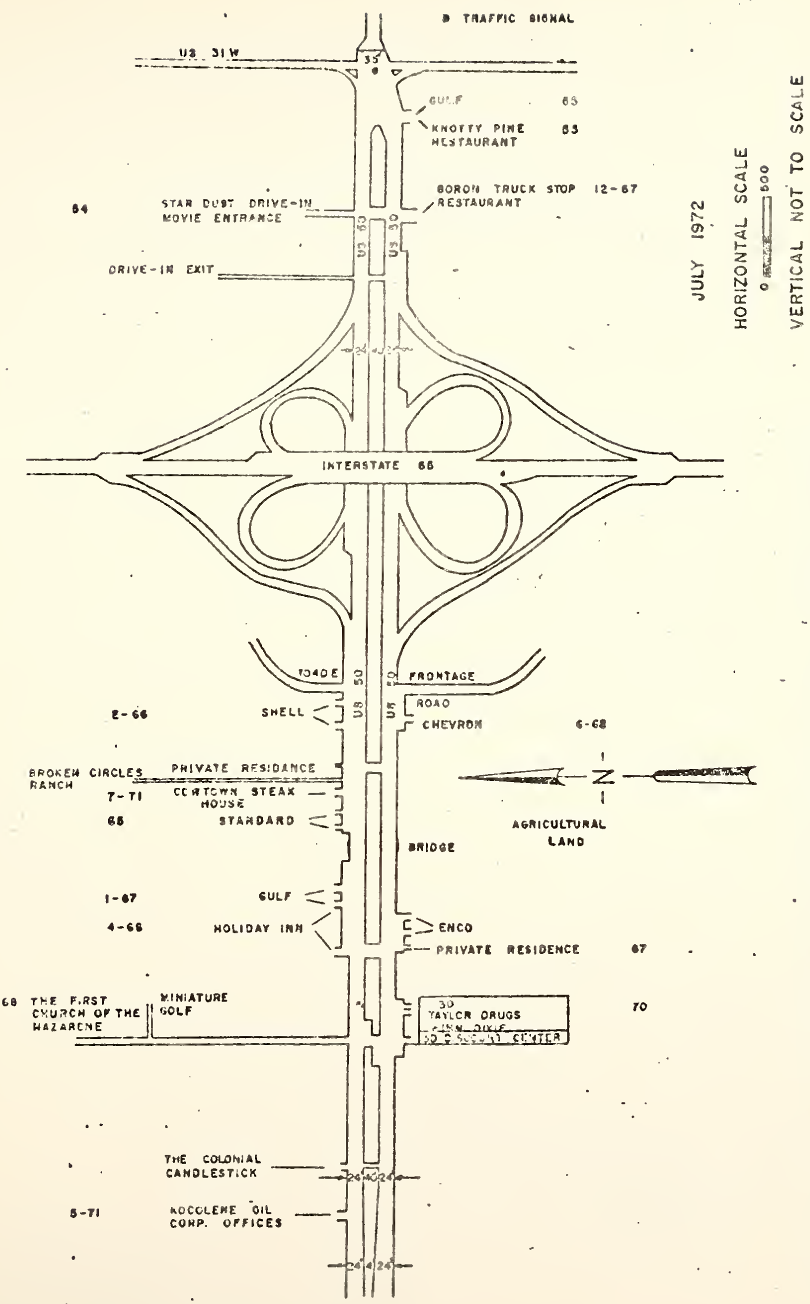


FIGURE 16. US 50 & INTERSTATE 65 INTERCHANGE

CASE III: Interchange of Interstate 74 and U.S. Route 231

The crossroute, U.S. Route 231 is a major north-south route in western Indiana. Of the land use surveyed in the interchange area the earlier development was surburban residential and agricultural business and only after the 1966 interchange opening did the highway oriented land uses of gasoline stations, motels, and highway maintenance buildings appear in a wave. This in turn promoted further residential building in the area. At this interchange the strip development into the nearby city, Crawfordsville, is much farther along reflecting U.S. Route 231's importance in intercity transport prior to becoming a feeder route to Interstate 74.

The Interstate grade separated structure and the crossroute development setbacks appropriately anticipate the day when volumes will warrant a four lane facility for U.S. Route 231. A service road for residential development in the Southeast quadrant represents sound planning in collecting and delivering vehicles to two entrance points at the crossroute more than 1000 feet apart. It is unfortunate that access to the crossroute was not similarly controlled at the commercial development nearer to the Interstate ramp terminals.

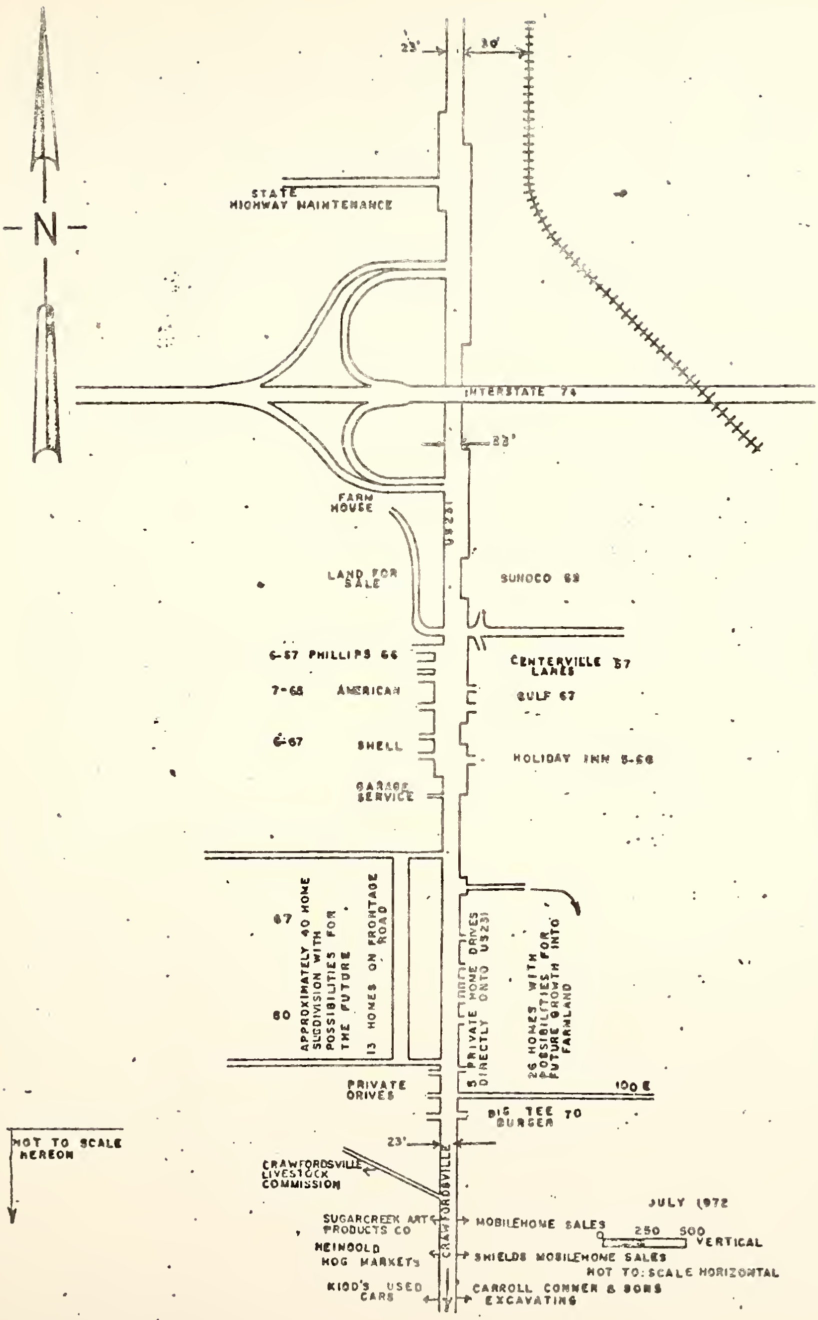


FIGURE 17. US 231 & INTERSTATE 74 INTERCHANGE

CASE IV: Interchange of Interstate 74 and State Route 44

This interchange opened in 1961 offered access to nearby Shelbyville in addition to the Farm Coop and the General Electric plant (Figure 18) already in the area. With the interchange access and a nearby industrial plant it is surprising that gasoline stations only located after a neighborhood shopping center was built in 1965 in the Southeast quadrant. General Electric expanded its operation in 1969 and since then studios, sales rooms, food marts, and additional retail operations have located in this area to take advantage of travel exposure and convenience though some have since closed.

Restricted by a seldom used railroad track to one side of the crossroad the interchange design chosen connects all ramp terminals at the east side of the crossroute. No land use transportation problems exist as the area is characterized by large land extensive industrial and business uses with few safely spaced access points along the crossroute. Although land coverage is greater than past case study examples, controlled crossroute access points reduce the potential hazards of crossroute conflicts.

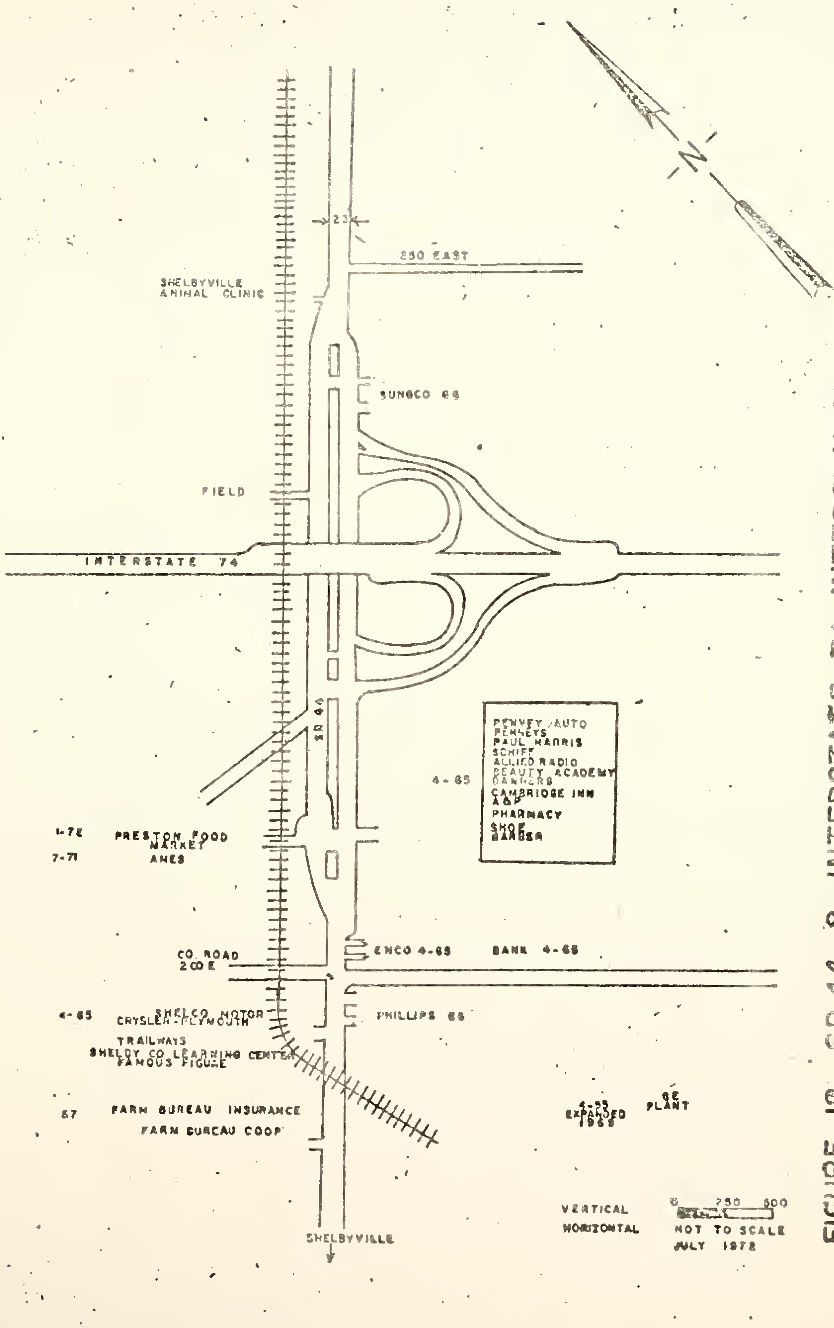


FIGURE 13. SR 44 & INTERSTATE 74 INTERCHANGE

CASE V: Interchange of Interstate 69 and State Route 8

This interchange area was found to be very densely developed with residential, commercial, and industrial land uses in a suburban area of a growing urban center, Auburn, whose 1970 population was 7350.

The timing of growth should be dramatic proof of the necessity for interchange area land use planning as part of highway planning in any similar suburban area. Before the Interstate and the interchange were opened in 1964 primarily residential homes lined State Route 8 into Auburn. There were also some very old established industrial plants located adjacent to the railroad tracks shown crossing State Route 8 in Figure 19. Small businesses requiring considerable inexpensive land moved out from Auburn accompanying the usual initial post Interchange wave of gasoline stations and motels. A rather large mobile home park when added to the importance of State Route 8 as an intercity route has steadily demanded more community services and created a stable market to support added gasoline stations, restaurants, drug stores, and two forthcoming neighborhood shopping centers.

The time between a general survey taken in January 1972 and a detailed survey undertaken in July 1972 saw three future high traffic generators (two shopping centers and an industrial park), a possible short order restaurant, and a completed drug store suddenly come into the development picture. Although the highway grade separated structure again provides for four lane operation, the critical segment between Auburn and the Interstate exhibits very little widening, driveway, nor land use planning.

Since East-West State Route 8 is the only major route through Auburn, future growth can reasonably be expected to continue along this band.

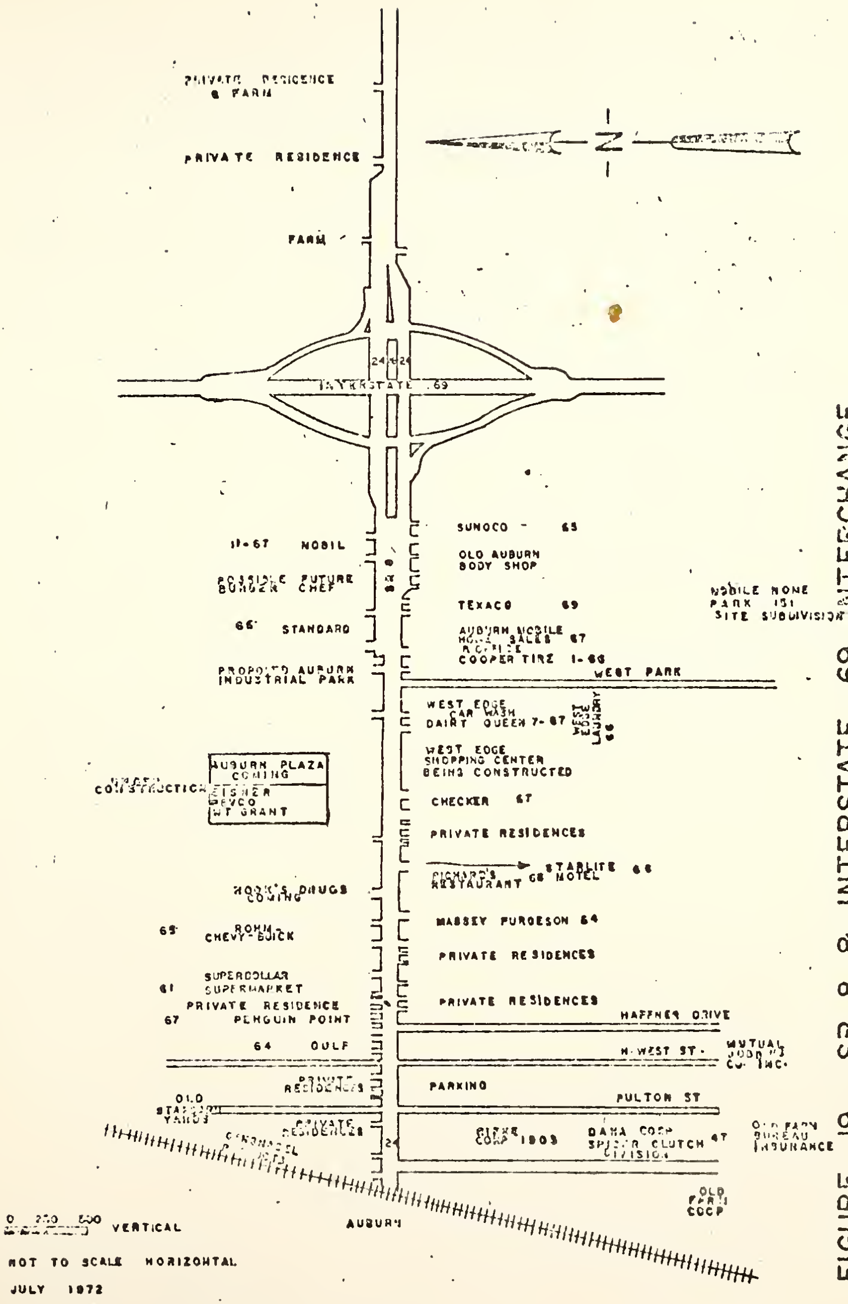


FIGURE 19. SR 8 & INTERSTATE 69 INTERCHANGE

CASE VI: Interchange of Interstate 74 and State Route 3

Greensburg has grown out along State Route 3 before and since Interstate 74 was opened in 1963. But, in contrast to other interchange areas many community services were established even before the Interstate was opened. Since 90% of this preinterstate construction occurred from 1960 through 1963 it might have been stimulated by anticipation of State Route 3's new function as the main access route connector to Greensburg. On the other hand, this growth could have been an outcome of natural urban development, a difficult distinction to make in evaluating Interstate economic impacts versus urban growth impacts.

In either case road user gasoline services still constituted the majority of post Interstate development. Also, in light of the amount of residential development already present, neighborhood shopping centers sprang up almost immediately. Therefore, the frontage along the crossroute leading into Greensburg is presently saturated with mixed road user, residential and local goods sale establishments with frequent driveways affecting crossroute service volumes.

With all these driveway conflicts and the potential development north of the Interstate, though temporarily halted by the urban boundary the Interstate seemingly forms, in addition to present continuing growth in the Southwest and Southeast quadrants back from existing crossroute strip development, State Route 3 may become the new "Main Street bottleneck" of Greensburg.

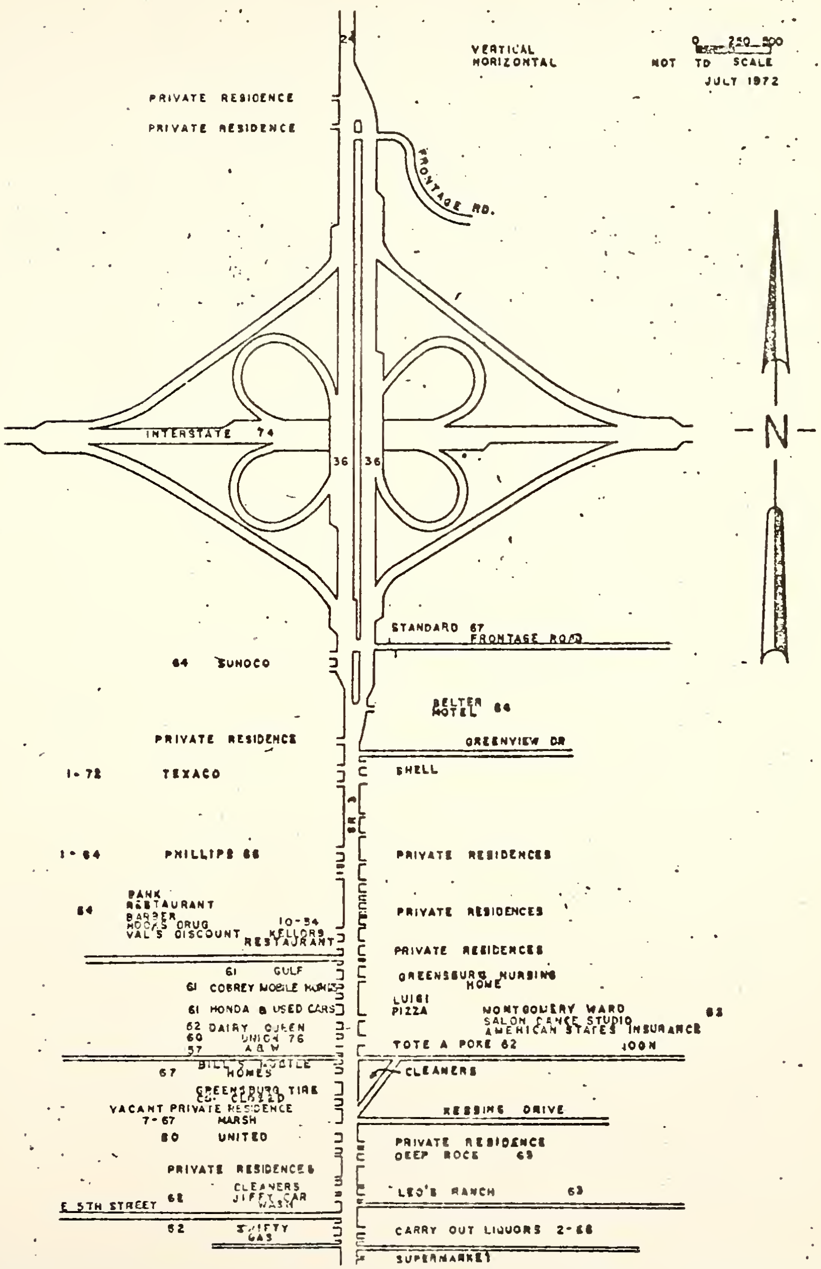


FIGURE 20. SR 3 & INTERSTATE 74 EAST INTERCHANGE

This concludes the case study progression of interchange development for suburban interchange areas. Although the observations are matter of fact, they prove conclusively that interchange land development will occur and should be planned for prior to the growth not post facto as is often the case.

Continuing now with four cases of urban fringe interchanges may give some added indication of what uncontrolled development effects may cause as an interchange area grows toward total nonagricultural use. The interchanges chosen from the urban fringe interchange classification are the junctions of Interstate 65 and U.S. Route 30, of Interstate 69 and State Route 3, of Interstate 70 and U.S. Route 41, and of Interstate 65 and U.S. Route 131.

CASE VII: Interstate 65 and State Route 30

Since this major interchange in northern Indiana has opened in 1968 the predominant new developments in the area have been gasoline stations and a motel-office-restaurant complex. Earlier development west of State Route 53 and presently along State Route 53 is more properly attributed to the tremendous growth of Merrillville, Indiana in the past few years. The development to either side of the Interstate is excellently access controlled by frontage roads leading back to residential, commercial, or business establishments from one safely placed crossroute access point. Two new large developments are expected east of the Interstate and should have access control with respect to U.S. Route 30 so as to allow only one or two main access points requiring some form of traffic control.

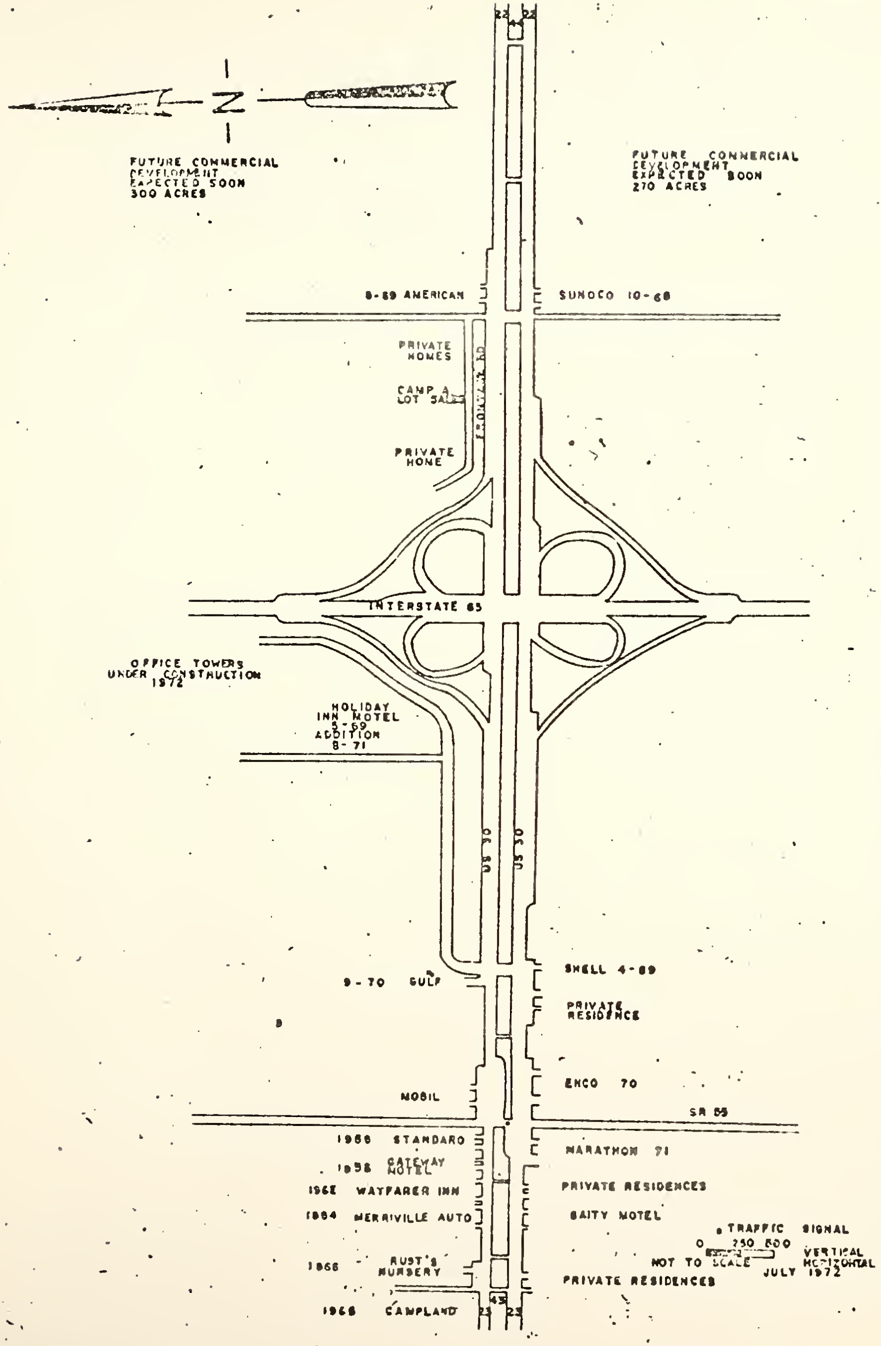


FIGURE 21. US 30 & INTERSTATE 65 INTERCHANGE

CASE VIII: Interchange of Interstate 69 and State Route 3

This interchange opened in 1962 with many industrial businesses, restaurants, or carry outs, and gasoline stations near the east end of the survey area already existing. It took the added locational advantage of an Interstate to spur additional service stations, land extensive businesses (e.g., furniture and auto or mobile home sales), industrial parks and large single family subdivisions to the area since then.

Driveway entrances while very frequently spaced are minor conflict points since State Route 3 is a four lane divided roadway with auxiliary lanes for turning movements. Access to industrial development in the Northeast and Southeast quadrants is well handled by a signalized intersection on the crossroute with the only possible future drawback being that, with increased interchange usage, backups from these signals along the crossroute may create a blockade of vehicles to confront a vehicle exiting from the Interstate ramp. Another saving feature of design of this interchange area is the collector road roughly parallel to the Interstate, in all quadrants, which collects traffic in a quadrant and distributes it to the crossroute at one point. However, these signalized points may again be too close to the off ramp terminals in this case with future delay and danger consequences possible as described above.

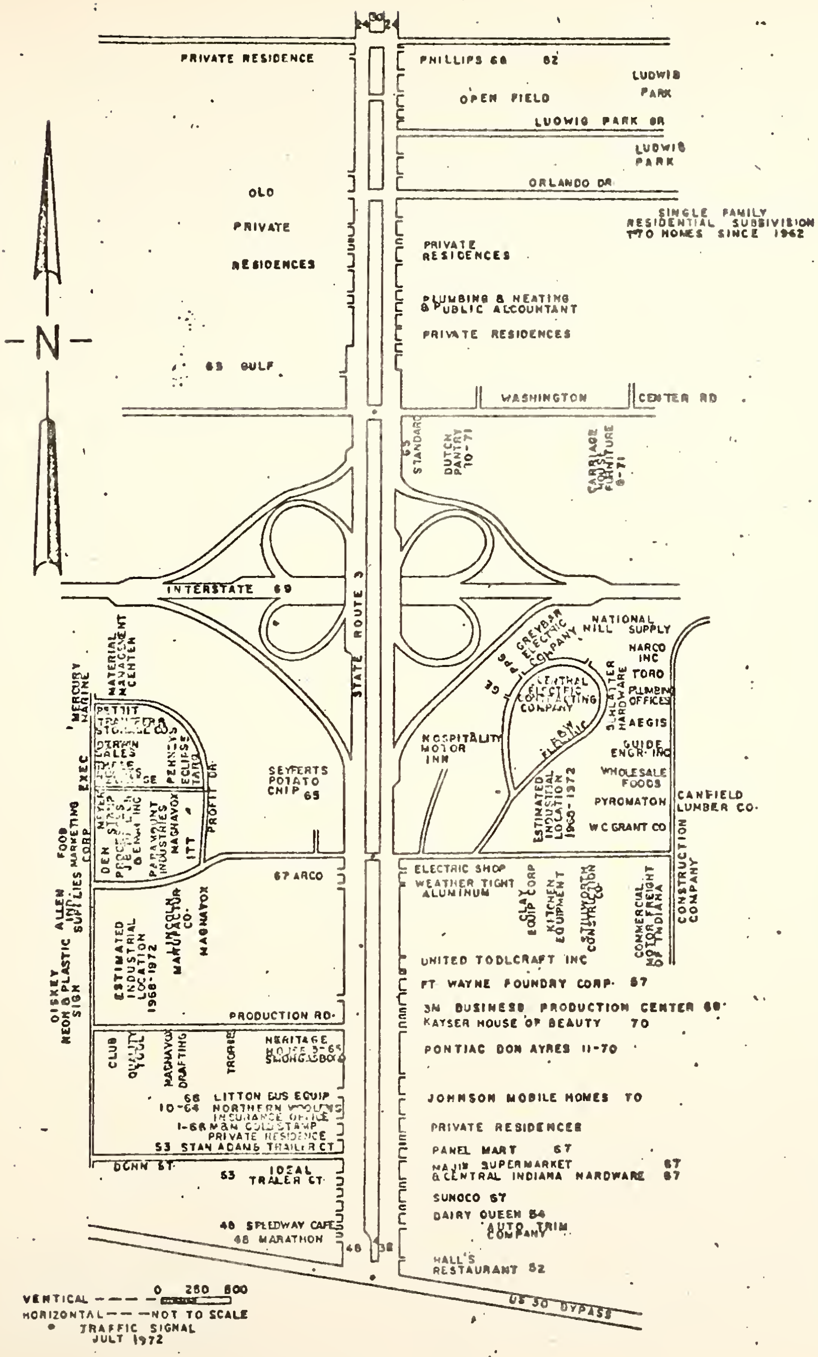


FIGURE 22. SR 3 & INTERSTATE 69 INTERCHANGE

CASE IX: Interchange of Interstate 70 and U.S. Route 41

As with Case VI urban development south from Terre Haute along SR 41 had virtually filled all land to the Terre Haute side of the Interstate before interchange opening. However, the south side of the Interstate followed a development pattern of first gasoline stations and motels, then mobile home sales, automobile sale rooms, automobile maintenance services, out of town show rooms, and finally a shopping center, in this case a regional shopping center. Unfortunately, with the exception of the regional shopping center and an as yet undeveloped 90 acre development tract all other access to U.S. Route 41 is on a "come-as-you-please-basis". The median strip, south of the Interstate, controls cross interferences but side driveway interferences for each direction of travel still exists.

Ramp terminals are signalized which may become a problem when other nearby crossroute signals in place or warranted in the future are interconnected to provide satisfactory traffic progression through the area.

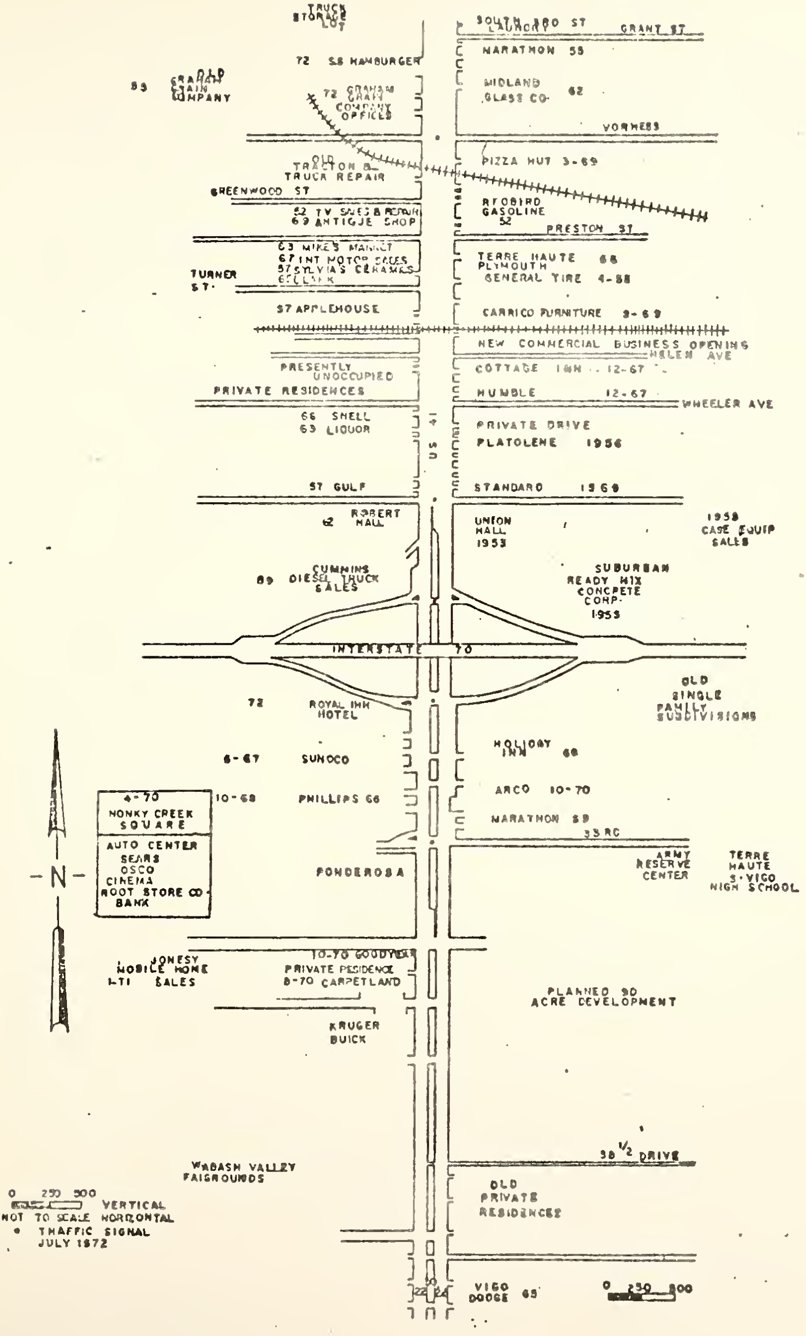


FIGURE 23. US 41 & INTERSTATE 70 INTERCHANGE

CASE X: Interchange of Interstate 65 and U.S. Route 131

Although this interchange was opened as part of the old U.S. Route 31 alignment, the area's development has exploded since 1965 with gasoline stations, car sales, service businesses, carry-outs, restaurants, mobile home sales, neighborhood shopping centers, and then regional shopping centers. Industrial parks and related road user establishments will be sure to utilize remaining undeveloped tracts east of the Interstate which features a railroad with several sidings already existing.

The interchange type is a partial cloverleaf with the on and off ramp terminals side by side on one side of the crossroute. Old heavy industrial development and more recent commercial development exist very close to these ramp terminals. Interstate right of way is so restricted in the Northwest quadrant that an access road to a hotel and to a service station terminates on the combined on-off ramp in that quadrant. Any modification in the existing interchange structure already restricted by a truck stop and railroad tracks in the Southeast quadrant and a large chemical plant and truck stop in the Southwest quadrant would be extremely costly at this late date.

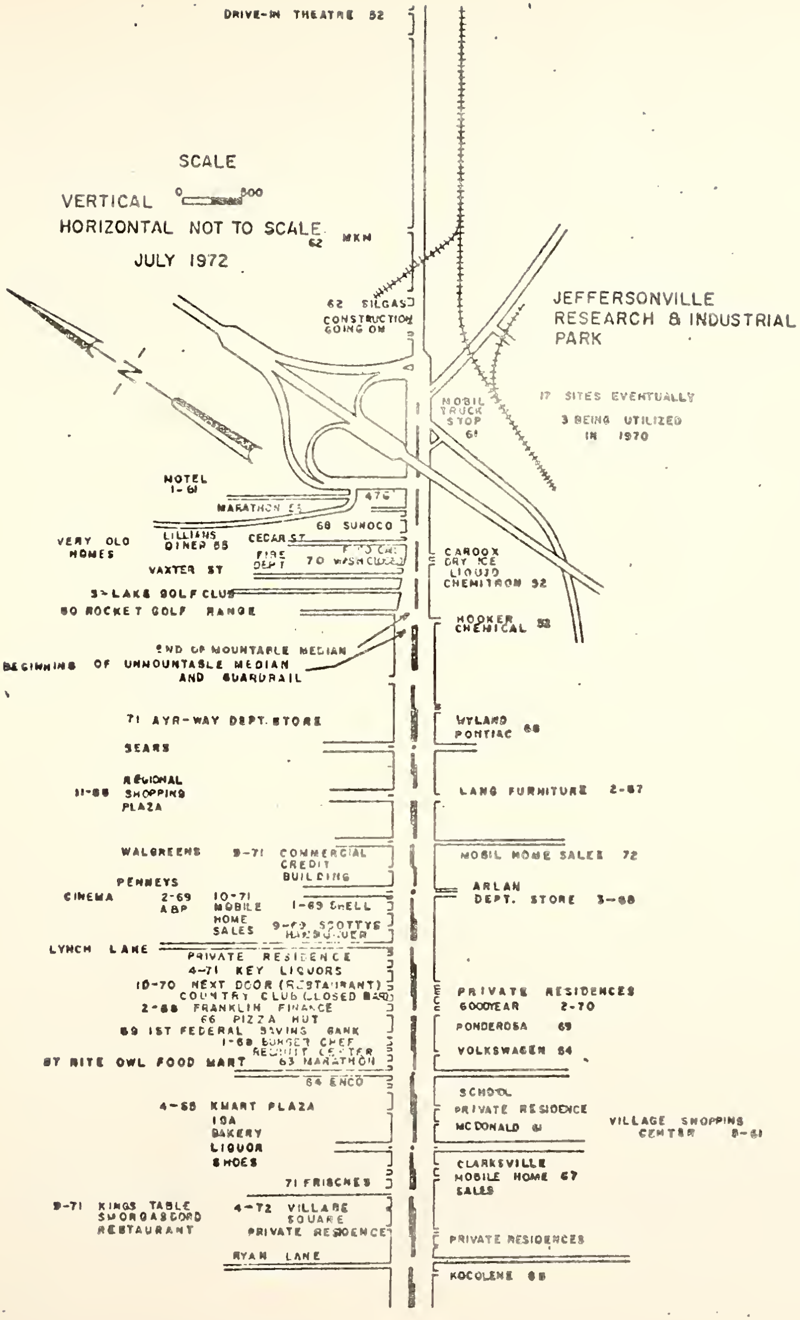


FIGURE 24. US 131 & INTERSTATE 65 INTERCHANGE

With the preceeding examples a progression of development at interchanges can be reasonably be hypothesized. The immediate effects of an interchange are an influx of gasoline stations, of truck stops, of motels, and of restaurants. Depending on the extent of residential growth before and during Interstate construction car sales, furniture stores, office buildings, carry-out restaurants, and related enterprises dependent on residential or work markets can be expected either immediately or as a second stage of development. Likewise, neighborhood shopping centers can be expected in every suburban interchange area and both neighborhood and regional shopping centers can be expected at urban fringe interchange areas. Industrial parks or industrial related businesses are more likely expected at urban fringe interchanges.

As was discovered in modeling, there is no one consistent land use development staging which can be described exactly by mathematical equation. Some interchange areas have community uses before road service uses. Others have industrial uses which lead to sooner influx of residential, of shopping, or of recreational uses. And while the development, as shown by years in Tables 7 and 8 for our cases studied, cannot presently be precisely classified, matched, or quantified, it is likely that some upper limit (saturation) of development is being approached in the differing areas. It is also certain that in spite of high land speculation there is a great amount of logic in locating land uses in interchange areas. It seems more likely, however, that this location decision process is more a dynamic than a static process. To quantify dynamic processes of land use change would require much more data for submodeling than is available in Indiana. Therefore, until such modeling is possible, perhaps the best use of the present reported data is as a record of the most developed interchange areas for use to plan for those interchanges not yet built or not as far along in the development process. This would provide for sensible recognition of the movement of business, residential development and industrial operations to new high exposure, highly accessible interchange areas. And, if development is planned, interchange growth can be economically beneficial to governments, to developers, and to area users.

TABLE 7. SUBURBAN INTERCHANGES CUMULATIVE LAND USE DEVELOPMENT

OPENING DATE	1962	1965	1966	1961	1964	1963
CASE STUDY / UNITS OF DEV. AFTER	I	II	III	IV	V	VI
0 YEAR	1	4	5	2	8	16
1 YEAR	2	6	9	2	11	19
2 YEARS	3	9	10	2	16	20
3 YEARS	5	12	10	2	21	22
4 YEARS	6	12	10	8	22	23
5 YEARS	9	13	10	10	23	24
6 YEARS	10	15	10	11	24	25
7 YEARS	11	15		12	24	25
8 YEARS	12			14	30	25
9 YEARS	12			14		26
10 YEARS	12			15		
11 YEARS				16		
1972 CONFLICT POINTS (> 10 VEHICLES) PER CROSS ROAD MILE	29	24	22	21	40	41
CLOSEST CROSSROUTE ACCESS POINT TO ANY RAMP TERMINAL	175'	250'	500'	175'	400'	250'

TABLE 8. URBAN FRINGE INTERCHANGES
CUMULATIVE LAND USE DEVELOPMENT

OPENING DATE	1968	1962	1969	1961
CASE STUDY / UNITS OF DEV. AFTER	VII	VIII	IX	X
0 YEAR	9	11	29	13
1 YEAR	12	13	37	15
2 YEARS	14	15	38	16
3 YEARS	16	18	41	18
4 YEARS	17	20		21
5 YEARS		24		23
6 YEARS		30		26
7 YEARS		36		36
8 YEARS		44		41
9 YEARS		51		46
10 YEARS		56		52
11 YEARS				55
1972 CONFLICT POINTS (> 10 VEHICLES) PER CROSS ROAD MILE	24	40	40	40
CLOSEST CROSSROUTE ACCESS POINT TO ANY RAMP TERMINAL	950'	325'	200'	ON RAMP

Illustrated Interchange Area Planning

This chapter will now discuss the available planning tools and subsequently show how some of these tools used together might have changed an existing Case Study area.

On the basis of the field survey there appears to be no enforced land use controls for most interchange areas. Except for such an absence, land use control should normally have been input to any land use model's base calibration. Land use controls cannot be disregarded in planning and will now be considered as the foundation of the following interchange land use planning discussion.

Police Powers

Among the police powers considered for use are zoning, subdivision, setback requirements, driveway permit, and official mapping.

"Zoning is the division of the community into zones or districts according to present and potential use of properties for the purpose of controlling and directing the use and development of the properties." (8) The effective use of zoning should result in an interchange area with reasonable density, positive distribution, and little congestion. "Unfortunately zoning has been a dismal failure because of the widespread use of exemptions and ready approval of requests for rezoning." (12)

One study shows that "applications have about a 90% chance of being granted in the first application." (22) "Part of the problem is that administrators look upon rezone applications near interchanges with no special awareness of the problem of interchange congestion." (8) In addition, field experience (Figures 15 through 24) suggests that lot by lot review of building permits and of driveway permits without the aid of an overall plan to give zoning a firm basis, results in a disfunctional land use conglomeration with frequent crossroute access as the final product of interchange area development. In essence, short range decisions and exceptions will lead to long range problems.

The need for comprehensive planning makes subdivision controls a favorable supplement to zoning control to achieve integrated interchange development. Subdivision controls specify development limits for lot arrangements, widths, length, depth, open space, water

and sewer systems, and easements for utilities. Subdivision controls can stipulate favorable crossroute access points, proper utilities, and safe property access to prevent critical crossroute conflicts near to other driver decision points and to keep land in interchange quadrants from becoming landlocked behind early post interchange crossroute strip development.

As subdivision controls are often only applicable down to a certain minimum number of lots and since zoning is weak by itself in controlling single lot land usage and layout, several other land use controls need to be included in an effective legislative package for interchange land use control.

Setback control will provide economic alternatives of increasing crossroute capacity through added width when the need arises and will reinforce zoning building placement requirements.

Official mapping of proposed widening or expansion for the future community street system if established wisely and democratically is a good long range planning prelude prior to establishing more detailed subdivision and setback controls.

Driveway permits can control the design, placement and spacing of driveway cuts from, abutting properties to a public road and in conjunction with subdivision and zoning controls could adequately prevent crossroute and ramp terminal conflict problems if enforced by knowledgable review boards.

Enforcement is a chief drawback to successful use of police power land use controls and so there is pressure to use more powerful land use control measures. These measures include eminent domain and special interchange districts.

Eminent Domain

Purchase and leaseback is a powerful though unpopular method of controlling land use at interchanges. Purchase of development rights or conservation easements are somewhat more fair to land owners and more acceptable to enforcement officials and legislators.

Excess condemnation when used by itself or in conjunction with a resale "for public purposes" as in urban renewal is another very effective power for controlling development. But, as evidenced by the numerous court suits claiming invasion of private rights, the fairness of widespread use of this power with regard to individual rights is not at all resolved. Economic and political costs and touchy legal bases are strong factors suggesting that interchange planners use this control on an extreme-need-only-basis.

The most acceptable type of eminent domain appears to be the purchase of access rights along the crossroutes. Accepted design techniques can then be used to control the number, type, and placement of access points.

Special Interchange Area District

Special districts, with precedent from waterfront districts have been suggested as a compromise way to stop scavenger speculation when the interchange and Interstate rights of way are first announced and to serve as an interim state control until the local planning commission does or does not act within a set time period.

With this brief summary of available land use controls and their potential use in interchange area planning and with the background of case studies development presented earlier, this chapter will culminate in an illustration of how Case Area V might have been planned. The final plan is not presented as the only design and control alternative but simply to demonstrate the use of good planning techniques. The trip generation rates used by type of establishment to demonstrate the number of driveway and of other crossroute conflicts are considered realistic estimates; however, while rates will be consistent for the planned and unplanned case, there is no attempt to substantiate these trip rates as the actual rates. As noted in the modeling phase of this research, rate determination would require an extensive field Origin-Destination Field Survey not within the capabilities of this research study.

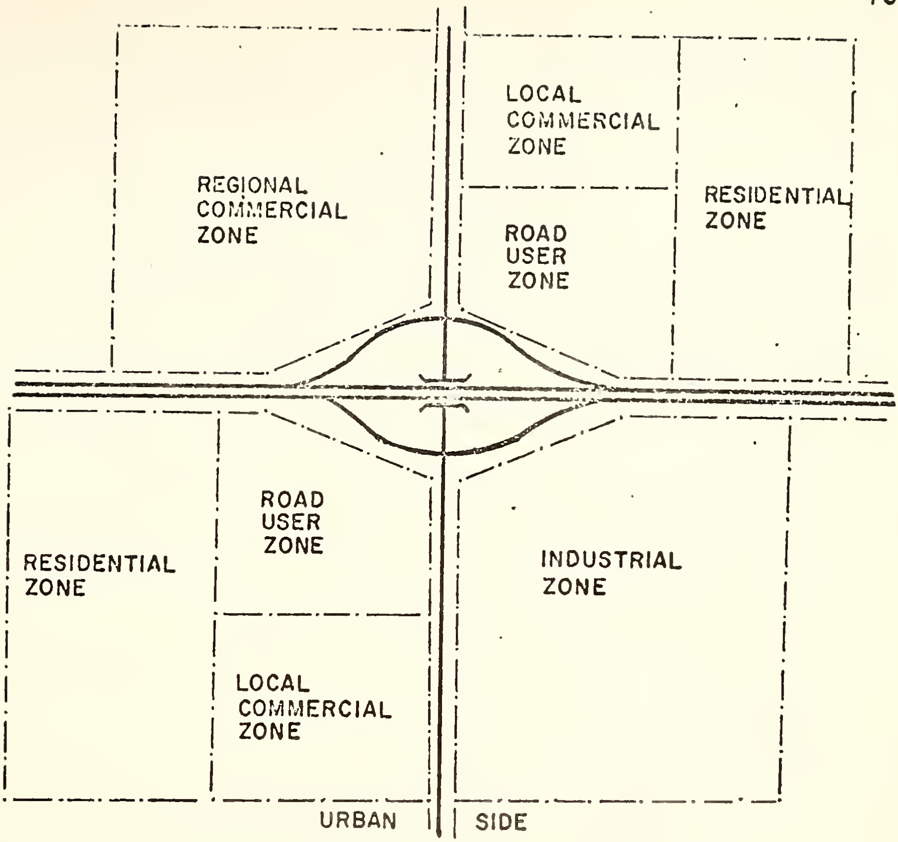


FIGURE 25. ZONING IN INTERCHANGE AREA PLANNING

Recognizing existing demands for land as tabulated in Chapters Four and Six this sample zone scheme has the following advantages over mixed development:

1. Road user services have first access off with right turn access.
2. Peak late afternoon work volumes are put to the urban side and on the opposite side peak early afternoon and evening shopping volumes to minimize peak travel and conflicts in the ramp terminal areas.
3. Residential zones are buffered from high generator land use types serving all classes of vehicles.

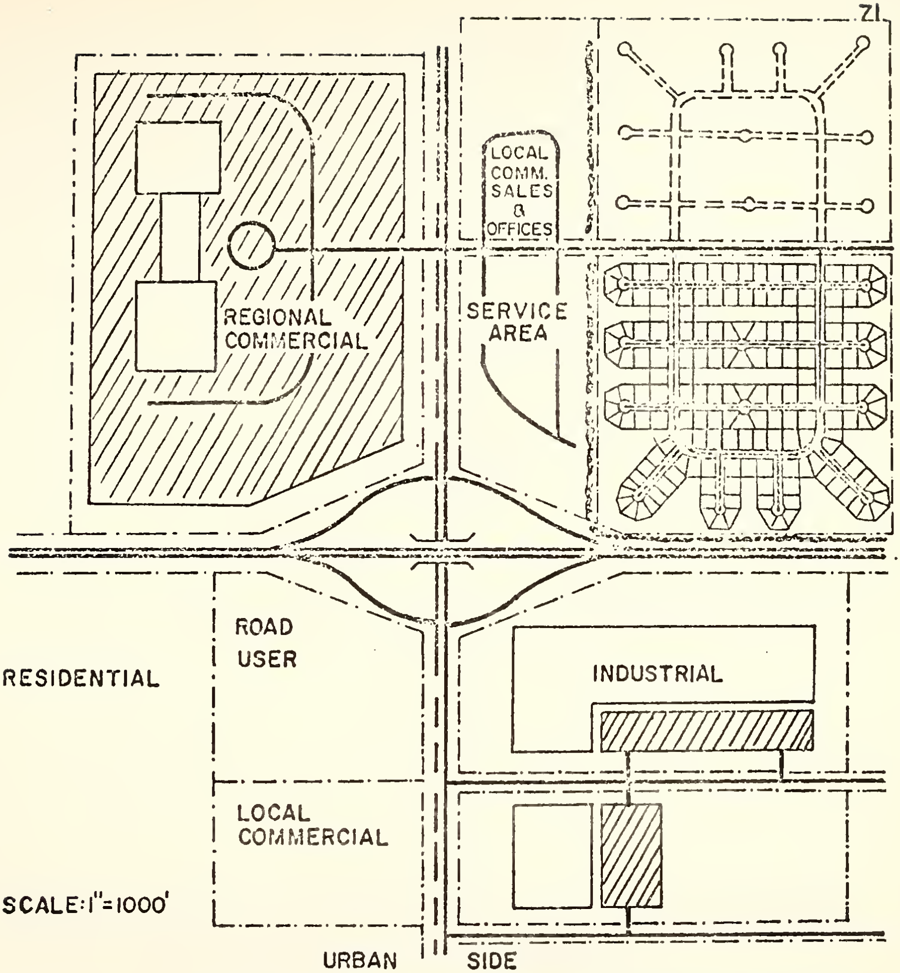


FIGURE 26. OFFICIAL MAPPING AND SUBDIVISION IN INTERCHANGE AREA PLANNING

Official Mapping:

1. Rights to roadway right-of-way within reasonable number of years for new and additional public roads and utility easements.

Subdivision:

1. Layout of lots, parking, streets, and utilities for subdivided plots of all land use types.

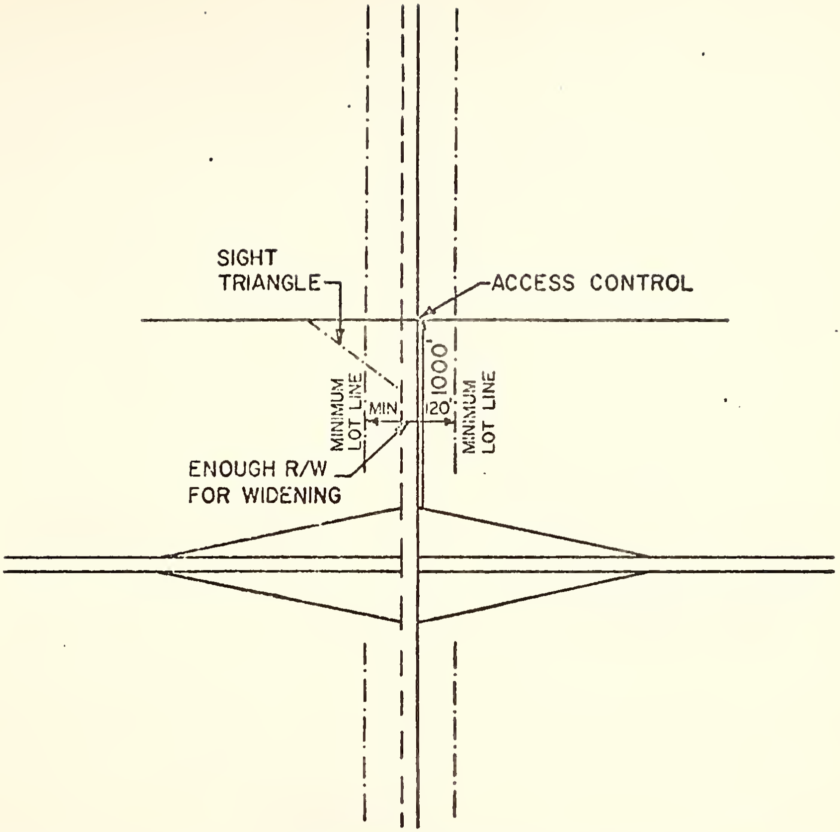


FIGURE 27. SETBACK REQUIREMENTS AND DRIVEWAY PERMITS IN INTERCHANGE AREA PLANNING

Setback Requirements:

1. Provides width for widening or for service roads.
2. Provides unobstructed ramp terminal views.

Driveway Permits:

1. Allow access review in light of entire interchange area plan.

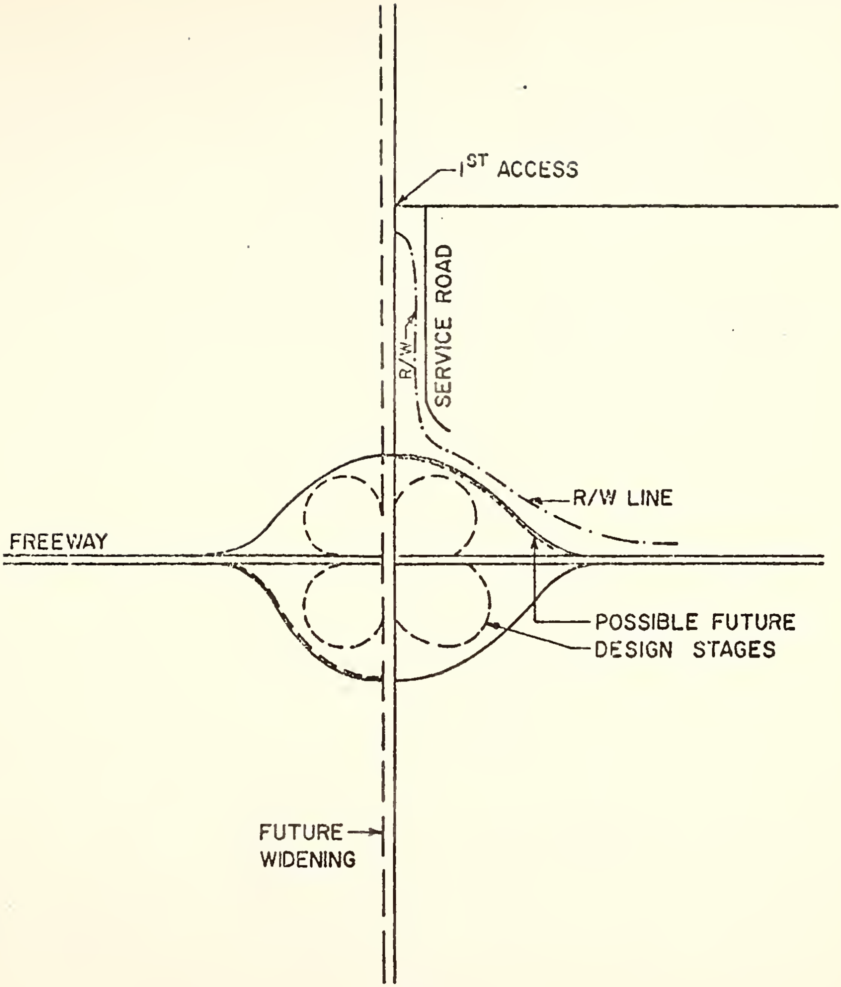


FIGURE 28. DESIGN CONTROLS IN INTERCHANGE AREA PLANNING

Design Options:

1. Flexible initial interchange area design
    a. Control crossroute access points
    b. Allow for economical design expansion to meet increasing capacity needs.

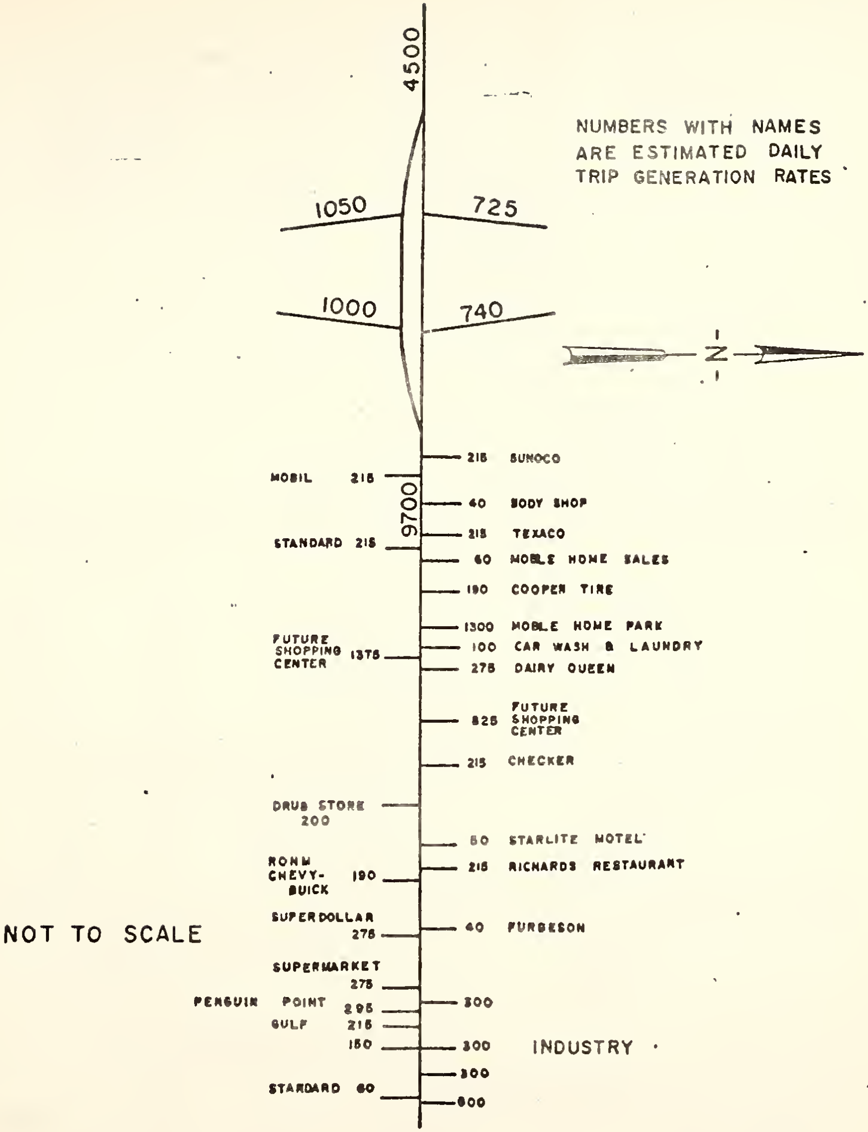


FIGURE 29. ESTIMATED DAILY TRIP GENERATION CHART FOR EXISTING I-69 & SR 28 DEVELOPMENT

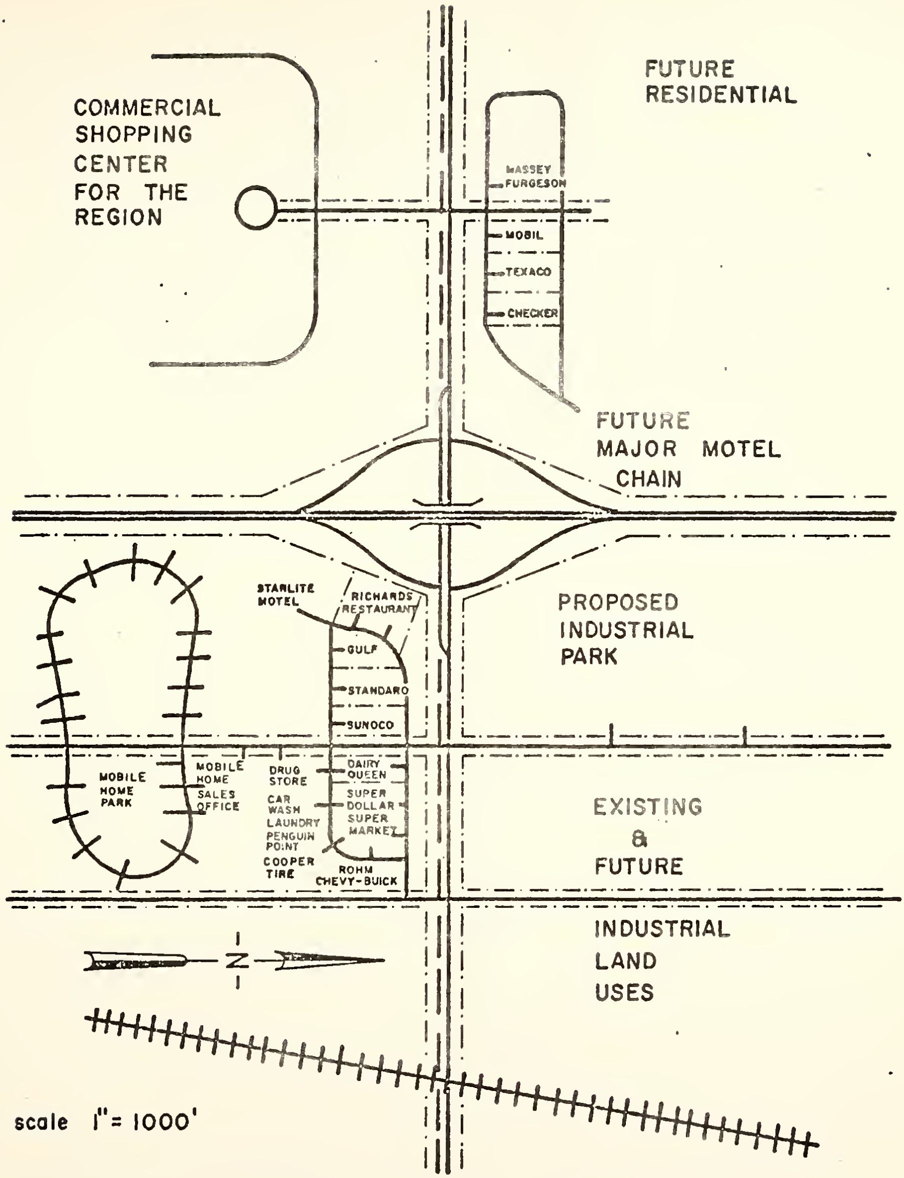


FIGURE 30. INTERCHANGE AREA PLAN ALTERNATIVE FOR I-69 & SR 8

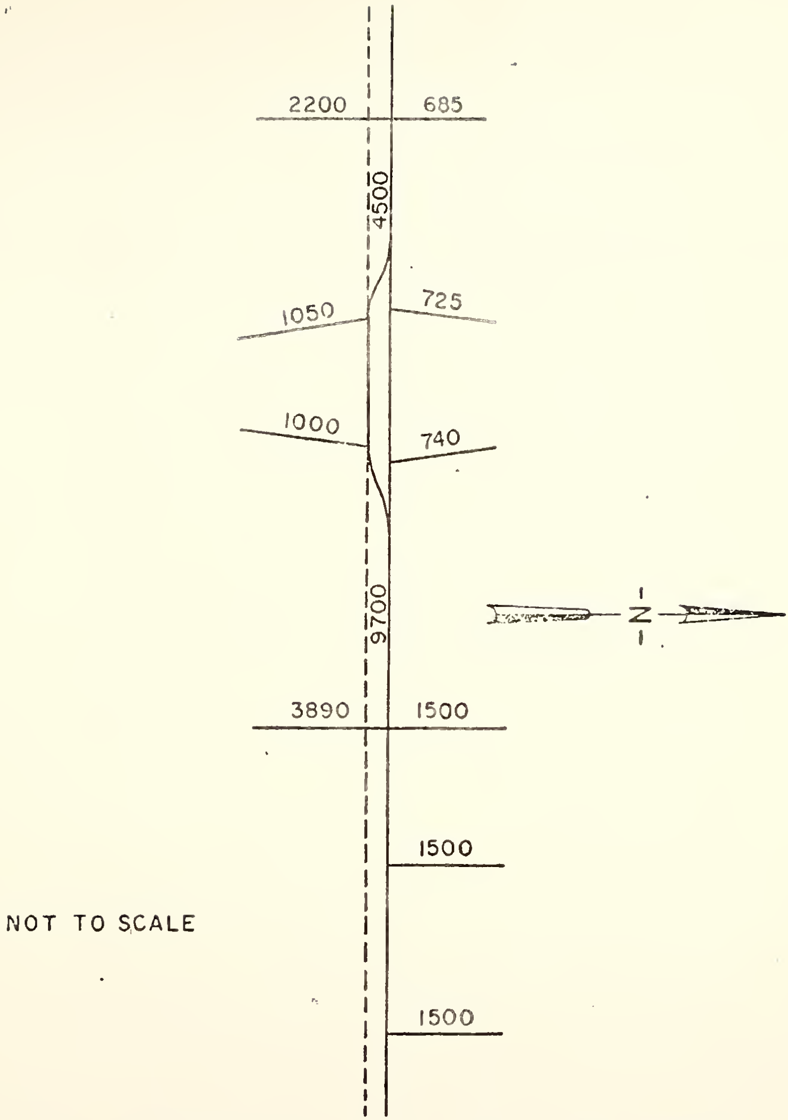


FIGURE 31. ESTIMATED DAILY TRIP GENERATION CHART FOR PLANNED I-69 & S.R. 8 DEVELOPMENT

The zoning scheme used as the base for all the proceeding diagrams is but one example of how land uses can be compatibility arranged to serve interchange area's community, private enterprise, and traffic flow requirements.

The example of Case Area V shows how all these controls might lead to beneficial comprehensive interchange area development.

The benefits such a suburban plan would offer are:

1. Optimum location of land use types as subjectively determined by timing development in the case studies.
2. Land use compatibility.
3. Controlled crossroute access points adequately spaced to provide selected but balanced use of crossroute intersections and to allow for favorable crossroute traffic signal control progression should the future situation warrant such signals.
4. Adequate crossroute right of way (120') to provide for a final crossroute crosssection consisting of a divided four lane roadway, with protected left turn bays in the median at crossroute intersection approaches, and with separate right turn lanes as are appropriate at the different crossroute intersections.

CHAPTER VII

SUMMARY AND CONCLUSION

A general survey of land use development at interchanges was successfully conducted at all rural and subjrban interchanges in January 1972. A more specific survey of land use change was conducted in July 1972 at suburban and urban interchanges. These two surveys are quantitatively summarized in Chapters 4 and 6 of this report respectively. The following discussion presents descriptive factors which it is strongly believed led to or explain these earlier facts and figures.

Road User Services

Since the non-toll freeways offer no commercial services to the motorists within the right of way, interchanges are prime targets for road user service developments which satisfy fuel, food, or lodging requirements. Of these the gasoline station is the service of greatest demand at freeway interchanges. These stations draw freeway drivers with acute fuel needs or with secondary fuel requirements conveniently fulfilled in conjunction with or in proximity to neighboring eating and lodging accommodations. Crossroute drivers with acute fuel needs or those attracted by the station's convenient location with respect to neighboring work, shopping, residential, recreation, or other trip end purposes are possible added interchange travelers. With a potential market so much broader than the traditional neighborhood station, which depends heavily on repeat business, it is logical that fuel companies are very speculative and competitive in acquiring highly accessible and highly visible plots on virtually free access crossroutes within interchange areas.

In competition among business establishments shortly after interchange opening, a multifunctional enterprise providing many

diverse but compatible services, such as, a truck-auto-and-lodging-services-stop, overshadows a neighboring single function establishment in terms of business generated. However, long range expected return for the single function establishments seems to override speculation risks inherent in the fact that the gasoline business

> Although supplying firms have been operating, in many cases, for several decades there appears to be a remarkable lack of information in most firms on such items as operating thresholds, amount of income derived from various activities (for example, in service stations gas sales vs TBA items), etc. that would enable them to estimate amounts that could realistically be paid for sites and the amount of land needed to support different levels of operation. (15)

Restaurants satisfying prepared food needs are limited in number reflecting the importance of adequate markets, of site advantages, of neighboring competition, and of supporting activities. Restaurants are operated in conjunction with automotive services, within neighborhood or regional shopping centers, within or near overnight lodging facilities of all types, strong seasonal or all weather recreational attractions, and large industrial complexes, or near high density residential developments.

Food carry-outs, small counter and grill setups, and vending machine refreshment bars are businesses catering more to quick service requirements of through Interstate travelers, short term shoppers, or blue collar workers employed in the interchange area.

Large chain motels, small business motels, trailer park and camping facilities are the three major lodging activities most likely to seek freeway interchange locations. The large chain motels seek the interchange for its first exposure to the freeway user, its convenience to overnight travelers, its amenities to the convention businessman and short term visitor that the downtown hotels with restricted parking, more noise and congestion, and more crime cannot offer. A motel's location proximate to interchange automotive, eating, and entertainment facilities is a desirable selling point. In fact, the latter two activities are often incorporated into the motel complex in the form of dining facilities, night clubs, or sports rooms and areas. Although these chain motels often build up in stages, the initial structure is large

enough for their owners to be extremely concerned about attracting a sufficient number of travelers. Therefore, interchanges around the larger cities, such as Fort Wayne, with a crosssection of tourists, businessmen, and overnight-through-travelers as possible customers, are the most likely to attract the Holiday Inns and the Howard Johnsons.

Small business motels can afford to locate in the absence of heavy freeway travel exposure, of an urban influence, or of strong recreational pull in the form of state parks and lake resorts, provided one of these is sufficiently strong enough to support economic survival. While less luxurious, these motels are generally less costly and more likely to attract the vacationing family on a short overnight, or long weekly stay. Interchanges near swimming, fishing, and hunting areas, as well as near cities below 10,000 population, or along heavily traveled freeway corridors are likely development areas.

Among American families, camping or trailer facilities are becoming popular for vacationing. The monetary savings and freedom of movement are prime factors in this growth of user interest. Therefore, the park owners must seek a location with enough acreage, enough exposure to the traveler, and in proximity to food supply and to family entertainment and recreation. The present optimum location for this blend of activities is logically near the interchange areas.

Open Space and Recreation

Often associated with the three types of lodging aforementioned are public and private recreational facilities. Public outdoor facilities included in this group are state parks, lakes, golf courses, and wildlife preserves. The cause and effect of the transportation-development process is iterative in that the interchange location and design was partially determined on the basis of present and projected major recreational opportunities in the surrounding landscape; then with the interchange completed there is a flood of public and private leisure activity development which in turn requires upgraded design and capacity considerations on the crossroute, and so on with time. This dynamic transportation improvement-land use development relationship

with subsequent interations promotes increased economic growth of formerly inaccessible natural landscape.

Less dependent on natural landscape but again looking for traveler exposure are land extensive private recreational facilities. Amusement parks, county fairs, bowling alleys, outdoor theaters, plaza cinemas, and other attractions all seek the volume, parking, land availability, and land accesibility that interchange areas offer.

Residential Development

Residential growth, especially on the fringe of established communities is frequently present along the freeway to utilize nearby interchanges for ready access to established centers. Generally detached single family home subdivisions are the largest in supply and demand in the residential market. Often the freeway makes it possible to commute twice the distance in a given time period as on a non access controlled highway facility. This has prompted people to allot a small time addition for the work trip in order to move out to more open surroundings where home and land are more reasonably priced than in city subdivisions. Though neighborhood shopping conveniences and friendships may be missing at first, they should come as the area development progresses. A number of suburban residential subdivisions will surely catalyze demand for supporting commercial, industrial, and recreational land uses.

The interchange areas are also excellent sites for the growing number of multifamily garden apartment and townhouse complexes. Land made available by the freeway and accessible by the interchanges can be planned for these high density uses successfully. With home services, such as laundry facilities, complete utilities and appliances, and maintenance and repair furnished and with modern social opportunities, such as nursery facilities, indoor and outdoor recreational areas, and entertainment rooms, not always found immediately in growing detached single family home subdivisions, provided as an integral part of the new apartment complexes, a full spectrum of living needs for different incomes within one planned environment can draw a sizeable housing market in the present highly mobile society.

Mobile home communities are becoming prominent in interchange areas. The growing demand for economic lodging in the face of increased material and labor costs is slowly changing the image of mobile home communities from hidden transient substandard groupings to well planned middle class communities for permanent residents.

Industrial Development

The work trip, a need mentioned under multifamily residential types, becomes increasingly shorter for outlying residential districts as industry relocates on available acreage near improved transportation routes, near the labor force, and to the modern break of bulk points while staying within areas served by needed utilities and preferably by a railroad. Wholesale houses, manufacturing plants, and supporting truck terminals all find interchange areas convenient and economical locations. Land is less expensive than downtown land. Trucks moving and delivering local goods can travel farther, faster, and more economically when terminals are located near the freeway. Land is available for adequate expansion especially for horizontal assembly line operations. And finally, freeway interchange areas offer excellent sites to coordinate land, air, and rail goods movements.

Commercial Complexes

With goods transfer already drawing industrial parks and wholesale centers to interchange locations, a further minimization of production-distribution cost can result with retail shopping centers located adjacent to the interchange. Employees for retail operations can reach work much easier. Neighborhood shopping centers and small individual retail stores are compliments to road user, residential, and industrial land uses discussed earlier. Advertising through extensive exposure is an important benefit of an adjacent freeway.

Regional shopping centers, while enjoying the interchange benefits mentioned above in addition offer parking and modern mall comparative shopping opportunities in a more relaxed and planned atmosphere than the

present congested, unconsolidated, and unplanned CBD shopping opportunities.

All preceeding sections summarize the possibilities for and the many existing activities of interchange area development by land use type. Each interchange may not have all the land use types discussed above but each interchange will reach its equilibrium level of land use interaction at some time after freeway construction. In an effort to develop a simplified measure of the level of development, the land use development model of Chapter V was calibrated. The model as developed can be useful as a utility measure of all interchange development. Should the independent factors for a given interchange as projected ten years into the future yield a development magnitude of 15 as opposed to a development magnitude of 5, it is safe to assume that priority for planning should be given "first" to the interchange whose projected ten year growth is 15. Hopefully, as a followup to pinpointing priority areas, "first" would mean that detailed planning and land use controls necessary to implement a plan, an example of which concludes Chapter Six, should be a part of planning the freeway location and interchange location. Resultant land use control along the crossroute should insure the continued safety and efficiency of interchange design components for the design life of the grade separated structure.

To briefly highlight some major findings and conclusions of this report:

1. No interchange land use development model has been developed in sufficient detail to predict the extent of individual land use types in an interchange area to date.
2. Successful interchange area planning must recognize the interests of highway road users, of businesses, and of land use and highway planners in devising the system of land use control least disruptive to existing preinterstate development while yielding the best long range benefits for all.

3. The model developed in this report will provide an aggregate rank utility measure of probable development at a future date for each rural interchange in Indiana. Available planning funds can then be directed toward the interchanges with a high rank which upon more detailed examination lack adequate comprehensive interchange land use planning.
4. Detailed comprehensive interchange land use planning should be based in a qualitative way on a similar type interchange or common aspects of different interchanges already well developed.
5. A dictionary of case suburban and urban fringe interchange studies for a qualitative reference in Indiana is initiated in Chapter Six. Substantial compilation of similar dictionaries in neighboring states and of dictionary expansion within Indiana could provide the broad data base required to prepare land use models of detailed land use types.
6. Aerial photographs must be taken at regular intervals, for instance every year, to be of use in land use change analyses of interchange areas.
7. Driveway permit applications should be standarized with minimum requirements and a complete centralized data bank maintained at the State level.
8. Field survey would be easiest method to update development at interchanges already inventoried. Purchase and deed county records may be a more accurate and complete source (in studying changes in land uses) for the surburban and urban fringe interchanges not yet inventoried.
9. Land use, design, and traffic controls must be combined into responsive and strong legal packages to be effectively enforced and used as a foundation for comprehensive interchange land use planning.

CHAPTER VIII
RECOMMENDATIONS FOR FURTHER RESEARCH

1. The weighted dependent variable of the final model in Chapter Five could be further refined by conducting a license plate survey of users of different land use types to determine local, crossroute, and Interstate destinations and to determine total generation rates of different land use types.
2. A study through a search of sales records could substantiate weights developed from comparative land use traffic generation rates.
3. Further case studies of suburban interchange areas compiled from detailed records of other states interchange area development studies would be useful along with further refinements in weighting different land use types in building a useful model of surburban interchange land use development.
4. The greater the data bank of a subcategory collected the more chance that changes and casual factors in the dynamic and speculative land use market can be quantitatively explained.
5. If driveway spacings, driveway land use served, roadway crosssection, speeds, travel time and delay, accident experience, interchange type, and volume of crossroute were available, more definite relationships of land use development to related safety and congestion on the ramps and on the crossroute might be developed if added case study areas were inventoried in addition to those already initially explored in this report.
6. An entire study on the legal potential of using new and innovative land use controls in implementing comprehensive interchange land use development planning satisfactory to local, state, and federal governmental planning agencies certainly needs to be done by someone with an adequate law background.

BIBLIOGRAPHY

BIBLIOGRAPHY

1. American Association of State Highway Officials, A Policy on Geometric Design of Rural Highways, (Washington, D.C., 1966).

2. Ashley, Roy H. and William F. Berard, "Interchange Development Along 180 Miles of I-94." Highway Research Record, Volume 96 (Washington, D.C.: Highway Research Board of the National Academy of Sciences, 1965), 46-58.

3. Dansereau, H. Kirk, A. Richard, and John R. Maiolo, "Specified Social Determinants of Attitudes Toward Community Planning and Zoning," Penn State Institute For Research on Land and Water Resources, Research Report Number 9, (1966).

4. Eyerly, Raymond W., "Land Use and Land Value in Four Interchange Communities - An Interim Report on the York Study." Penn State Institute For Research on Land and Water Resources, Research Report Number 7, (1966).

5. Garrison, William L., "Land Uses In The Vicinity of Freeway Interchanges: Models of Land Use Developments and Related Traffic Flows." The Bureau of Public Roads U.S. Department of Commerce, (May 31, 1961).

6. Highway Research Board, Highway Capacity Manual: Highway Research Board Special Report 87, (Washington, D.C., National Academy of Sciences National Research Council, 1966).

7. Horwood, Edgar M., Charles Graves, and Clark D. Rogers, "An Evaluation of Land - Use Control Procedures at Freeway Approaches," Highway Research Board Bulletin, Volume 288 (Washington, D.C.: Highway Research Board of the National Academy of Sciences, 1961), 67-82.

8. Indiana State Highway Commission, "The Traffic Interchange and Community Growth."

9. Isibor, E.I., "Modeling The Impact of Highway Improvements on the Value of Adjacent Land Parcels." Ph.D. thesis, Purdue University, Joint Highway Research Project, December 1969.

10. Kuhn, Herman A.J., "Planning Implications of Urban and Rural Freeway Interchanges." Journal of Urban Planning and Development Division, Volume 95 (April 1969), 81-92.

11. Kuhn, Herman A.J., "The Factors Which Influence Traffic Generation at Rural Highway Service Areas." For Presentation at the Annual Meeting of the Highway Research Board, (January 1968).

12. "Land Use and Development at Highway Interchanges: A Symposium," Highway Research Board Bulletin, Volume 288 (Washington, D.C.: Highway Research Board of the National Academy of Sciences, 1961).

13. Lawrence, W.M.S. and Associates, Inc., "Interchange Area Planning: A Special Study For Lake County, Indiana," (January 1967).

14. Marble, Duane F., "User Services and the Demand for Land at Interchange Points." Highway Research Board Bulletin, Volume 288 (Washington, D.C.: Highway Research Board of the National Academy of Sciences, 1961), 25-31.

15. Mason, "Interchange Development and Land Use Controls,".ongoing study at University of Alabama.

16. Michael, Harold L., Traffic Characteristics and Measurements," class notes Purdue University CE 564, (Fall 1971).

17. Ohio Department of Highways, "Factors Influencing Land Development-Subdivision Development Study - Interstate 71-Franklin County," (September 1970).

18. Ostle, Bernard, Statistics In Research, (Ames, Iowa, The Iowa State University Press, 1963).

19. Pendelton, William C., "An Empirical Study of Changes in Land Use at Freeway Interchanges," Traffic Quarterly, Volume 19 (January 1965), 89-100.

20. Sauerlender, Owen H., Donaldson Jr., Robert B., and Richard D. Twark, "Factors That Influence Economic Development at Non-Urban Interchange Locations," Penn State Institute for Research on Land and Water Resources, Research Report 9, (1966).

21. Spears, John D. and Charles H. Smith, A Study of Land Development and Utilization at Interchange Areas Adjacent To Interstate 40 in Tennessee (Knoxville, Tennessee: University of Tennessee, Highway Research Program and U.S. Bureau of Public Roads, September, 1968).

22. State Highway Commission of Wisconsin, Interchange Area Planning in Wisconsin (Madison, Wisconsin: Planning and Research Division, State Highway Commission of Wisconsin, undated).

23. Statistical Computer Library for Purdue University, BMD02R Statistical Program, (1972).

24. Thiel, Floyd I., "Highway Interchange Area Development," Highway Research Record, Volume 96 (Washington, D.C.: Highway Research Board of the National Academy of Sciences, 1965), 24-45.

25. Utah State Department of Highways, Utah Land Use at Interchange Study Instructional Manual, (Salt Lake City, Utah: Utah State Department of Highways and the U.S. Bureau of Public Roads, undated).

26. Vodrazka, Walter C., "Subclassification of The State Highway System of Indiana Based on Synthesis of Intercity Travel," (Joint Highway Research Project, School of Civil Engineering, Purdue Unviersity, Lafayette, Indiana, February 15, 1968).

GENERAL REFERENCES

1. Adkins, William G., "Economic Impacts of Expressways in Dallas and San Antonio," Traffic Quarterly, (July 1959), pp. 333-345.

2. Bardwell and Merry, "Measuring The Economic Impact of a Limited-Access Highway on Communities, Land Use and Land Value," Highway Research Board Bulletin, Volume 268 (Washington, D.C.: Highway Research Board of the National Academy of Sciences, 1960).

3. Barton- Aschman Associates, Inc., "Case Studies of Selected Interchange Areas," Highway and Land Use Relationships in Interchange Areas, Supplementary Report Number 3, (Evanston, Illinois, November 1963).

4. Barton- Aschman Associates, Inc., "Commuter Parking at Highway Interchanges," (Chicago, Washington, D.C., and Minneapolis-St. Paul, March 1970).

5. Barton- Aschman Associates, Inc., "Current Laws and Practices Affecting Interchange Area Planning," Highway and Land Use Relationships in Interchange Areas, Supplementary Report Number 1, (Evanston, Illinois, November 1963).

6. Barton- Aschman Associates, Inc., Highway and Land Use Relationships in Interchange Areas, Supplementary Report Number 2, (Evanston, Illinois, November 1963).

7. Brand, Daniel, Brian Barber, and Michael Jacobs, "Technique for Relating Transportation Improvements and Urban Development Patterns," Highway Research Record, Volume 207 (Washington, D.C.: Highway Research Board of the National Academy of Sciences, 1967), pp. 53-67.

8. Chapin, F. Stuart, Jr., "A Model for Simulating Residential Development," AIP Journal, (May 1965), pp. 120-125.

9. Coyle, John J., H. Kirk Dansereau, John C. Frey, and Robert D. Pashek, "Interchange Protection and Community Structure," Highway Research Record, Volume 75 (Washington, D.C.: Highway Research Board of the National Academy of Sciences, 1965), pp. 62-74.

10. Dansereau, H. Kirk, John C. Frey, and Robert D. Pashek, Highway Development: Community Attitudes and Organization," Highway Research Record, Volume 16 (Washington, D.C.: Highway Research Board of the National Academy of Sciences, 1963), pp. 44-59.

11. Draper and Smith, Applied Regression Analysis, (New York, John Wliey & Sons, Inc., 1966).

12. Ellis, Raymond H., "Modeling of Household Location: A Statistical Approach," Highway Research Record, Volume 207 (Washington, D.C., Highway Research Board of the National Academy of Sciences, 1967). pp. 42-52.

13. Flaherty, Mark C., "Commercial Highway Service Districts and the Interstate," Highway Research Record, Volume 96 (Washington, D.C., Highway Research Board of the National Academy of Sciences, 1965), pp. 8-18.

14. Frankland, "Land Use Controls at Freeway Interchanges in California," Traffic Quarterly, (October 1965), pp. 541-555.

15. Frey, J.C., Dansereau, Pashek, and Twark, "Land-Use Planning and the Interchange Community," Highway Research Board Bulletin, Volume 327 (Washington, D.C., Highway Research Board of the National Academy of Sciences, 1962), pp. 56-66.

16. Gern, Richard C. and Harvey R. Joyner, "Cross Route Access Design in Interchange Areas," Barton Aschman Associates, Inc., (undated).

17. Greenbie, Barrie Barstow, "Interchange Planning in a Rural Area," Traffic Quarterly, (April 1970), pp. 265-277.

18. H.O.P. Committee of Ohio, "Interchange Area Development: X Marks The Spot," (undated).

19. Horwood, Edgar M., "Community Consequences of Highway Improvement," Highway Research Record, Volume 96 (Washington, D.C., Highway Research Board of the National Academy of Sciences, 1965), pp. 1-7.

20. Kirk, H. T., "County Guide for Growth: AB Zoning at Interchange Quadrants 1967-1987," unpublished paper, (Purdue University, April 1967).

21. Lathrop, George T. and John R. Hamburg, "An Opportunity Accessibility Model For Allocating Regional Growth," AIP Journal, (May 1965), pp. 45-103.

22. Levin, D. R., "The Highway Interchange Land-Use Problem," Highway Research Board Bulletin, Volume 288 (Washington, D. C., Highway Research Board of the National Academy of Sciences, 1961), pp. 1-24.

23. Neve, James P., Jr., "A Scoreboard for Interchanges," Traffic Engineering, Volume 32, Number 12, (September 1962), pp. 22,23,35.

24. Pendelton, William C., "Land Use at Freeway Interchanges," Traffic Quarterly, (October 1961), pp. 535-546.

25. Pennsylvania State University, "Blairsville: A Bypass Study," (University Park, Pennsylvania, 1962).

26. Sawhill, R.B., Ebner. J.W., "Freeways and Residential Neighborhoods," Highway Research Record, Volume 149 (Washington, D.C., Highway Research Board of the National Academy of Sciences, 1966), p. 57.

27. Schlager, Kenneth J., "A Land Use Plan Design Model," AIP Journal, (May 1965), pp. 103-111.

28. Schlager, Kenneth J., "A Recursive Programming Theory of the Residential Land Development Process, Highway Research Record, Volume 126, (Washington, D.C., Highway Research Board of the National Academy of Sciences, 1966), pp. 24-31.

29. Stanhagen, William H., "Highway Interchange and Land-Use Controls," Highway Research Board Bulletin, Volume 288, (Washington, D.C., Highway Research Board of the National Academy of Sciences, 1961), pp. 32-60.

30. Stuart, D.G., "Multiple-Purpose Freeway Land Development," Highway Research Board Bulletin, Volume 217 (Washington, D.C., Highway Research Board of the National Academy of Sciences, 1959), pp. 1-8.

31. Swerdloff, Carl N. and Joseph R. Stowers, "A Test of Some First Generation Residential Land Use Models," Highway Research Record, Volume 126 (Washington, D.C., Highway Research Board of the National Academy of Sciences, 1966), pp. 38-59.

32. Utah State Department of Highways, "Utah: Land Use Control Methods For Interchange Areas," June 1967.

33. Walsh, Stuart Parry, "Some Effects of Limited Access Highways on Adjacent Land Use," Highway Research Board Bulletin, Volume 227 (Washington, D.C., Highway Research Board of the National Academy of Sciences, 1959(, pp. 78-82.

34. Wilson, "Case Studies of Effects of Roads on Development," Highway Research Record, Volume 115, (Washington, D.C., Highway Research Board of the National Academy of Sciences, 1966), pp. 10-18.

35. Witenstein, M., "A Report on Application of Aerial Photography to Urban Land Use Inventory, Analysis, and Planning, Photo Engineering, Volume 22, (1956), pp. 656-663.

APPENDICES

APPENDIX A

DEFINITIONS

TBA - An abbreviation for Tires, Batteries, and Accessories

Arterial Highway - "A highway primarily for through traffic, usually on a continuous route" (7)

Expressway - "A divided arterial highway for through traffic with full or partial control of access and generally with grade separations at major intersections" (7)

Freeway - "An expressway with full control of access" (7)

Frontage Road - "A road contiguous to an generally paralleling an expressway, freeway, parkway, or through street and so described as to intercept, collect, and distribute traffic desiring to cross, enter, or leave such highway and which may furnish access to property that otherwise would be isolated as a result of the controlled-access feature; sometimes called a service road." (7)

Auxiliary Lane - "The portion of roadway adjoining the traveled way for parking, speed change, or for other purposes supplementary to the through traffic movement." (7)

Ramp Terminal - "The general area where a ramp connects with a roadway. Ramps have both entrance and exit terminals. The entrance terminal relates to a merging condition, the exit terminal relates to a diverging condition." (7)

Capacity - "Capacity is the maximum number of vehicles which has a reasonable expectation of passing over a given section of a lane or a roadway in one direction (or in both directions for a two-lane or a three-lane highway) during a given time period under prevailing roadway and traffic conditions." (7)

Level of Service - "Level of service is a number of factors, which include speed and travel time, traffic interruptions, freedom to maneuver, safety, driving comfort, and convenience, and operating costs." (7)

These definitions thus far are as given in The Highway Capacity Manual's Chapter Two (7). Other terms used less frequently in this paper, such as, Control of Access, Crosssection components, Cross-sectional Design, Traffic Lane, Intersection, Channelization, Traffic Control Devices, Peak-Hour Traffic, Bottleneck, and subclassifications of these terms are also

used as defined in Chapter Two of the Highway Capacity Manual (7).

Interchange Design- Diamond, cloverleaf, partial cloverleaf, and directional interchanges are terms used in this report as defined and illustrated in "A Policy on Geometric Design of Rural Highways" 1965, Chapter IX (1).

UNITS OF DEVELOPMENT

Truck Stop - A gasoline business which serves trucks and automobiles, has a cafeteria, and has minimal overnight bedding for truck drivers.

Motel-

Large Chain Motel - Any motel with a minimum of 40 rental units and with a dining room.

Small Business Motel - Any motel with a maximum of 40 rental units.

Restaurant - Any eating business establishment having a minimum of twenty seats.

Recreation Park - An amusement park.

Trailer Park - An area capable of accomodating five or more overnight camper trailers.

Mobile Home Sales - A business dealing in sales of mobile home trailers.

Public Facilities - A golf course, lake, or a similar public recreation area.

Food Service - A carry-out food business with at least 10 parking spaces provided.

Small Local Business - A single store dealing in sales of retail merchandise.

Service Station - A gasoline business with a minimum of two islands capable of serving at least four automobiles at one time. These stations usually have a snack bar with food self-service vending machines or a small short order grill to serve the traveler quickly.

Industry (Or Regional Office) - Any industrial business covering an area of at least one acre and at most ten acres.

Neighborhood Shopping Center - Any shopping center composed of at least one supermarket and one major department store.

Low Density Residential - Any subdivision of ten to twenty dwelling units with an average individual lot size of more than one acre.

Medium Density Residential Subdivision - Any residential subdivision greater than twenty units and less than eighty units with average individual lot sizes less than one acre.

Educational - Any level school.

Regional Shopping Center - Any shopping center with two or more department stores.

Rural Interchange - All interchanges not classified as being Suburban or Urban Fringe Interchanges.

Surburban Interchange - Any interchange with at least 8 units of development and within four miles of a city center whose 1970 Census Population is greater than 8000 or within seven miles of a city whose 1970 Census Population is greater than 70000 or within ten miles of a city center whose 1970 Census Population is greater than 400000.

Urban Fringe Interchange - Any interchange with at least 15 units of development and within four miles of a city center whose 1970 Census Population is greater than 70000.

APPENDIX B

INVENTORY FORMS AND QUESTIONNAIRES

INTERCHANGE IDENTITY			
INTERSTATE INTERCHANGE	INTERSTATE ROUTE	CROSSROUTE	INTERCHANGE TYPE

PLOT INFORMATION					
APPROXIMATE COMPLETION DATE	AVAILABLE UTILITIES	AREA DIMENSIONS	EXTENT OF FACILITY	ACCESS DISTANCE	QUADRANT

FIRM & PERMIT FILE NUMBER	INTERCHANGE INFORMATION - GENERAL		
	CROSSROUTE VOLUME	THROUGH VOLUME	INTERCHANGE OPENING

LOCATION MAP

GENERAL INFORMATION

FIGURE B1. DATA SHEET FOR FIELD SURVEY

Purdue University
Civil Engineering Bldg.
W. Lafayette, Indiana 47907

Dear Sir:

I am presently conducting a study of Interstate Interchange Areas and Development in Indiana. The purpose of this work is to enable highway planners and designers to plan future interchanges for development most likely to occur at such interchanges and for development in a locational pattern most advantageous to all concerned. Principally, business owners both before and after the Interstate opening, highways' travelers, and highway engineers will be the beneficiaries of improved planning for integrated and complimentary use of interchange lands.

To be worthwhile, any recommendations for the future should be realistically based on the present demand for and on the present use of land. It is with this background that I come to you for one important data item in reconstructing the sequence of development around the present interchanges. This item is <u>when to the best of your knowledge did the establishment you own and/or operate first open for business</u>.

Since this information is most vital to this study and so to the completion of my master's degree program at Purdue, I <u>would be most grateful if you would fill in and mail the attached prestamped form as soon as possible</u>.

With Sincere thanks,

Lawrence P. Fabbroni
Graduate Assistant
in Research

When to the best of your knowledge did the establishment you own and/or operate first open for business?

Month ____________ Year ____________

Any added criticisms you might have about the highway or neighboring development are welcome.

FORM NO.________

APPENDIX C

INVENTORY CODING PROCEDURES

Card Number(s) (Columns 1-2)	Description
01	Ramp Volumes
03&05	Crossroute Volumes & Dates
07,08,09,10,11,12	Parallel Route Volumes
15,16,17,18,19,20	Parallel Route's Distances From Interstate Interchanges
23,24,25,26	1950 Urban Center Populations
27,28,29,30	1960 Urban Center Populations
31,32,33,34	1970 Urban Center Populations
41	Interchange Opening Date
43	Interchange Road User Development & Date
51,61,71,81,	Interstate Mileage To Travel To Urban Center By Minimum Time Path
52,62,72,82	Two-Lane Rural Mileage To Travel To Urban Center By Minimum Time Path
53,63,73,83,	Multi-Lane Highway Mileage To Travel To Urban Center By Minimum Time Path
54,64,74,84	Urban Highway Mileage To Travel To Urban Center By Minimum Time Path

INTERCHANGE NUMBER LISTING

Interchange	Code	Interchange	Code
I-65&US30	0113	I-74&Acton Road	4748
I-65&SR8	0114	I-74&Pleasant View	5401
I-65&SR2	0115	I-74&London Road	5402
I-65&SR10	1401	I-74&Fairfield(S-1054)	5403
I-65&SR114	1402	I-74&SR9	5404
I-65&US231	1403	I-74&SR44	5405
I-65&US24	1404	I-74&SR244	5407
I-65&US52	4002	I-74&SR189(Middletown)	5301
I-65&SR32	4003	I-74&US421	6501
I-65&SR39	4004	I-74&SR 3	6502
I-65&US52	4005	I-74&Rossburg	6503
I-65&SR267	4006	I-74&SR229	6601
I-65&SR334	4007	I-74&SR101	6801
I-74&SR63	4301	I-74&SR1	6702
I-74&Stringtown Road	4201	I-74&US52	6701
I-74&US41	4202	I-70&Post Road	4746
I-74&SR25	4101	I-70&Mount Comfort	4801
I-74&US231	4102	I-70&SR9	4802
I-74&SR32	4103	I-70&SR109	4901
I-74&SR75	4010	I-70&SR3	4902
I-74&SR39	4601	I-70&New Lisbon	4903
I-74&Pittsboro	4602	I-70&SR1	5001
I-74&SR267	4603	I-70&Centerville (S-168)	5002
I-70&US40	5901	I-70&US35	5003
I-70&Darwin Road	5902	I-70&US27	5004
I-70&US41	5903	I-70&SR227	5005
I-70&SR46	5904	I-70&US40	5006
I-70&SR59	5801	I-69&SR38	3703
I-70&SR243	4501	I-69&SR9	3702
I-70&US231	4502	I-69&SR109	3701
I-70&Little Point	5601	I-69&SR67	3604
I-70&SR39	4604	I-69&SR128	3602
I-70&SR267	4605	I-69&US35	3601
I-65&US31	6401	I-69&SR26	3203
I-65&SR46	6402	I-69&SR22	3202
I-65&SR58	6403	I-69&SR18	3201
I-65&US31A	7001	I-69&SR218	2103
I-65&SR50	7002	I-69&SR5	2102
I-65&SR250	7003	I-69&US224	2101
I-65&SR256	7004	I-69&Lafayette Center Rd.	1807
I-65&SR56	8001	I-69&US24	1806
I-65&SR160	8002	I-69&SR14	1805
I-65&SR698(Memphis)	8401	I-69&US30	1804
I-65&US31W	8402	I-69&SR3	1803
I-65&SR60	8403	I-69&SR327	1802
I-65&US131	8404	I-69&SR1	1801
I-74&Post Road	4745	I-69&Co. Rd. 11A	0804

INTERCHANGE NUMBER LISTING CONTINUED

Interchange	Code
I-69&SR8	0803
I-69&US6	0802
I-69&SR4	0801
I-69&US20	0706
I-69&SR590	0705
I-69&SR727	0704
I-69&SR120	0703
I-69&US27	0701

URBAN CENTER INDENTIFICATION

Interstate Route		I-70East	I-70West	I-74West	I-74East
Urban Center	1	Indianapolis	Indianapolis	Danville, Ill.	Indianapolis
	2	Greenfield	Plainfield	Covington	Shelbyville
	3	Carthage	Mooresville	Veedersburg	Rushville
	4	Shirley	Danville	Attica	Greensburg
	5	New Castle	Spencer	Waynestown	Batesville
	6	Spiceland	Greencastle	Crawfordsville	Brookville
	7	Mooreland Dublin	Brazil	Ladoga	Lawrenceburg
	8	Mt.Auburn Cambridge	Terre Haute	Jamestown	Cincinnati Area
	9	Milton	Vincennes	Lebanon	
	10	Hagerstown	W. Terre Haute	Brownsburg	
	11	Rushville	Rockville	Danville, Ind.	
	12	Centerville		Indianapolis	
	13	Richmond			
	14	Connersville			
	15	Lynn			

URBAN CENTER IDENTIFICATION

Interstate Route		I-65 North	I-65 South	I-69 North
Urban Center	1	Indianapolis	Indianapolis	Indianapolis
	2	Lebanon	Columbus	Noblesville
	3	Thornton	Brownstown	Anderson
	4	Frankfort	Seymour	Middletown
	5	Zionsville	North Vernon	Chesterfield
	6	Lafayette	Connersville	Elwood
	7	Mulberry	Austin	Yorktown
	8	Delphi	Madison	Muncie
	9	Brookston	Scottsburg	Alexandria
	10	Rensselaer	Salem	Albany
	11	Monticello	Charleston	Gaston
	12	Wolcott	Sellersburg	Eaton
	13	Remington	Louisville Area	Summitville
	14	Goodland	Edinburg	Dunkirk
	15	Fowler	Franklin	Fairmount
	16	Kentland	Greenwood	Hartford
	17	Brook		Upland
	18	Morocco		Gas City
	19	Francesville		Marion
	20	Kouts		Montpelier
	21	Hebron		Van Buren
	22	Lowell		Warren
	23	Cedar Lake		Bluffton

URBAN CENTER IDENTIFICATION

Interstate Route		I-65 North	I-69 North
Urban Center	24	Crown Point	Huntington
	25	Valparaiso	Markle
	26	Gary Area	Ossian
	27	Monon	Decatur
	28		Roanoke
	29		Fort Wayne
	30		Columbian City
	31		Churubusco
	32		Garrett
	33		Auburn
	34		Avila
	35		albion
	36		Kendalville
	37		Lagrange
	38		Waterloo
	39		Butler
	40		Angola
	41		Fremont

ROUTE NUMBER LISTING

CODE	ROUTE	CODE	ROUTE
0010	SR 1	0480	SR 48
0020	SR 2	0490	SR 49
0030	SR 3	0520	US 52
0090	SR 9	0530	SR 53
0270	US 27	0550	SR 55
0310	US 31	0620	SR 62
0311	US 31A	0670	SR 67
0312	US 31E	1350	SR 135
0320	SR 32	1360	US 136
0360	US 36	2210	SR 221
0370	SR 37	2310	US 231
0380	SR 38	2340	SR 234
0400	US 40	2360	SR 236
0410	US 41	3030	SR 303
0420	SR 42	3270	SR 327
0440	SR 44	4210	US 421
0460	SR 46		

CARD 01 Ramp Volumes

COLUMN(S)	CODE	DESCRIPTION
1-2	01	Ramp Volumes Card
3-6	See Interchange Number Listing	
7-11	Average Ramp Volume Off (ADT)	
12-16	Average Ramp Volume On (ADT)	
17-20	Year Of Volume Counts	
21-25	Average Ramp Volume Off (ADT)	
26-30	Average Ramp Volume On (ADT)	
31-34	Year Of Volume Counts	
35-39	Average Ramp Volume Off (ADT)	
40-44	Average Ramp Volume On (ADT)	
45-48	Year of Volume Counts	
49-53	Average Ramp Volume Off (ADT)	
54-58	Average Ramp Volume On (ADT)	
59-62	Year of Volume Counts	

CARD 03 Crossroute Volumes

COLUMN(S)	CODE	DESCRIPTION
1-2	03	Crossroute Volume Card
3-6	See Interchange Number Listing	
7-11	Crossroute Volume To One Side of Interstate (ADT)	
12-16	Crossroute Volume To Other Side of Interstate (ADT)	
17-21	Crossroute Volume To One Side of Interstate (ADT)	
22-26	Crossroute Volume To Other Side of Interstate (ADT)	
27-31	Crossroute Volume To One Side of Interstate (ADT)	
32-36	Crossroute Volume To Other Side of Interstate (ADT)	
37-41	Crossroute Volume To One Side of Interstate (ADT)	
42-46	Crossroute Volume To Other Side of Interstate (ADT)	
47-51	Crossroute Volume To One Side of Interstate (ADT)	
52-56	Crossroute Volume To Other Side of Interstate (ADT)	
57-61	Crossroute Volume To One Side of Interstate (ADT)	
62-66	Crossroute Volume To Other Side of Interstate (ADT)	
67-71	Crossroute Volume To One Side of Interstate (ADT)	
72-76	Crossroute Volume To Other Side of Interstate (ADT)	

CARD 05 Year Of Crossroute Volume Count

COLUMN(S)	CODE	DESCRIPTION
1-2	05	Year Of Crossroute Volume Count Card
3-6	See Interchange Number Listing	
7-10	Year Of Crossroute Volume Counts Card 03 for Cols. 7-16	
11-14	Year Of Crossroute Volume Counts Card 03 for Cols. 17-26	
15-18	Year Of Crossroute Volume Counts Card 03 for Cols. 27-36	
19-22	Year Of Crossroute Volume Counts Card 03 for Cols. 37-46	
23-26	Year Of Crossroute Volume Counts Card 03 for Cols. 47-56	
27-30	Year Of Crossroute Volume Counts Card 03 for Cols. 57-66	
31-34	Year Of Crossroute Volume Counts Card 03 for Cols. 67-76	

CARDS 07,08,09,10,11,12 Parallel Route Volumes

COLUMN(S)	CODE	DESCRIPTION
1-2	07	Parallel Route 1 Volume Card
	08	Parallel Route 2 Volume Card
	09	Parallel Route 3 Volume Card
	10	Parallel Route 4 Volume Card
	11	Parallel Route 5 Volume Card
	12	Parallel Route 6 Volume Card
3-6	See Interchange Number Listing	
7-10	See Route Number Listing	
11-15	1952 Parallel Route Volume Count To One Side of Crossroute (ADT)	
16-20	1952 Parallel Route Volume Count To Other Side of Crossroute (ADT)	
21-25	1958 Parallel Route Volume Count To One Side of Crossroute (ADT)	
26-30	1958 Parallel Route Volume Count To Other Side of Crossroute (ADT)	
31-35	1962 Parallel Route Volume Count To Other Side of Crossroute (ADT)	
36-40	1962 Parallel Route Volume Count To Other Side of Crossroute (ADT)	
41-45	1966 Parallel Route Volume Count To One Side of Crossroute (ADT)	
46-50	1966 Parallel Route Volume Count To Other Side of Crossroute (ADT)	
51-55	1969 Parallel Route Volume Count To One Side of Crossroute (ADT)	
56-60	1969 Parallel Route Volume Count To Other Side of Crossroute (ADT)	

CARDS 15,16,17,18,19,20 Parallel Route Distance From Interstate Interchange

COLUMN(S)	CODE	DESCRIPTION
1-2	15	Parallel Route 1 Distance Card
	16	Parallel Route 2 Distance Card
	17	Parallel Route 3 Distance Card
	18	Parallel Route 4 Distance Card
	19	Parallel Route 5 Distance Card
	20	Parallel Route 6 Distance Card
3-6	See Interchange Number Listing	
7-10	See Route Number Listing	
11-13	Parallel Route Distance From Interstate Interchange Measured Along Crossroute	

CARDS 23,27,31 Urban Center Populations

COLUMN(S)	CODE	DESCRIPTION
1-2	23,27,31	Urban Center Population Card
3	5	1950
	6	1960
	7	1970
4-5	Interstate Route Number	
6	1	East of Indianapolis
	2	North of Indianapolis
	3	West of Indianapolis
	4	South of Indianapolis
7-12	Urban Center 1 Population	
13-18	Urban Center 2 Population	
19-24	Urban Center 3 Population	
25-30	Urban Center 4 Population	
31-36	Urban Center 5 Population	
37-42	Urban Center 6 Population	
43-48	Urban Center 7 Population	
49-54	Urban Center 8 Population	
55-60	Urban Center 9 Population	
61-66	Urban Center 10 Population	
67-72	Urban Center 11 Population	
73-78	Urban Center 12 Population	

See Urban Center Identification Table

CARDS 24,28,32 Urban Center Populations

COLUMN(S)	CODE	DESCRIPTION
1-2	24,28,32	Urban Center Population Card
3	5	1950
	6	1960
	7	1970
4-5	Interstate Route Number	
6	1	East of Indianapolis
	2	North of Indianapolis
	3	West of Indianapolis
	4	South of Indianapolis
7-12	Urban Center 13 Population	
13-18	Urban Center 14 Population	
19-24	Urban Center 15 Population	
25-30	Urban Center 16 Population	
31-36	Urban Center 17 Population	
37-42	Urban Center 18 Population	
43-48	Urban Center 19 Population	
49-54	Urban Center 20 Population	
55-60	Urban Center 21 Population	
61-66	Urban Center 22 Population	
67-72	Urban Center 23 Population	
73-78	Urban Center 24 Population	

See Urban Center Identification Table

CARDS 25,29,33 Urban Center Populations

COLUMN(S)	CODE	DESCRIPTION
1-2	25,29,33	Urban Center Population Card
3	5	1950
	6	1960
	7	1970
4-5	Interstate Route Number	
6	1	East of Indianapolis
	2	North of Indianapolis
	3	West of Indianapolis
	4	South of Indianapolis
7-12	Urban Center 25 Population	
13-18	Urban Center 26 Population	
19-24	Urban Center 27 Population	
25-30	Urban Center 28 Population	
31-36	Urban Center 29 Population	
37-42	Urban Center 30 Population	
43-48	Urban Center 31 Population	
49-54	Urban Center 32 Population	
55-60	Urban Center 33 Population	
61-66	Urban Center 34 Population	
67-72	Urban Center 35 Population	
73-78	Urban Center 36 Population	

See Urban Center Identification Table

CARDS 26,30,34 Urban Center Populations

COLUMN(S)	CODE	DESCRIPTION
1-2	26,30,34	Urban Center Population Card
3	5	1950
	6	1960
	7	1970
4-5	Interstate Route Number	
6	1	East of Indianapolis
	2	North of Indianapolis
	3	West of Indianapolis
	4	South of Indianapolis
7-12	Urban Center 37 Population	
13-18	Urban Center 38 Population	
19-24	Urban Center 39 Population	
25-30	Urban Center 40 Population	
31-36	Urban Center 41 Population	
37-42	Urban Center 42 Population	
43-48	Urban Center 43 Population	
49-54	Urban Center 44 Population	
55-60	Urban Center 45 Population	
61-66	Urban Center 46 Population	
67-72	Urban Center 47 Population	
73-78	Urban Center 48 Population	

See Urban Center Identification Table

CARD 41 Interchange Opening Data

COLUMN(S)	CODE	DESCRIPTION
1-2	41	Interchange Opening Data Card
3-6	See Interchange Number Listing	
7-10	Interchange Opening Year	

CARD 43 Interchange Road User Development

COLUMN(S)	CODE	DESCRIPTION
1-2	43	Interchange Road User Development Card
3-6	See Interchange Number Listing	
7	1	Service Station (Maximum 3 Service Islands)
	2	Service Station+Restaurant (Minimum 20 Seats)
	3	Large Chain Motel (Minimum 40 Units)
	4	Small Chain Motel (Maximum 40 Units)
	5	Restaurant (Minimum 20 Seats)
	6	Truck Stop (Auto-Truck-Food-Lodging Service)
	7	Neighborhood Shopping Center (1Supermarket,1Dept.Store)
	8	Regional Shopping Center (Minimum 2 Major Dept. Stores)
	9	Service Station+Short Order (Grill+Maximum 20 Seats)
8-11	Year Of Establishment 1 Opening	
12	Code of Establishment 2 (Same as column 7)	
13-16	Year of Establishment 2 Opening	
17	Code of Establishment 3 (Same as column 7)	
18-21	Year of Establishment 3 Opening	
22	Code of Establishment 4 (Same as column 7)	
23-26	Year of Establishment 4 Opening	
27	Code of Establishment 5 (Same as column 7)	
28-31	Year of Establishment 5 Opening	
32	Code of Establishment 6 (Same as column 7)	
33-36	Year of Establishment 6 Opening	
37	Code of Establishment 7 (Same as column 7)	
38-41	Year of Establishment 7 Opening	
42	Code of Establishment 8 (Same as column 7)	
43-46	Year of Establishment 8 Opening	
47	Code of Establishment 9 (Same as column 7)	
48-51	Year of Establishment 9 Opening	
52	Code of Establishment 10 (Same as column 7)	
53-56	Year of Establishment 10 Opening	

CARD 43 continued Interchange Road User Development

COLUMN(S)	CODE DESCRIPTION
57	Code of Establishment 11 (Same as column 7)
58-61	Year of Establishment 11 Opening
62	Code of Establishment 12 (Same as column 7)
63-66	Year of Establishment 12 Opening
67	Code of Establishment 13 (Same as column 7)
68-71	Year of Establishment 13 Opening
72	Code of Establishment 14 (Same as column 7)
73-76	Year of Establishment 14 Opening

CARDS 51,52,53,54 Measured Distances From Urban Centers To Interchanges

COLUMN(S)	CODE	DESCRIPTION	
1-2	51	Interstate	Highway Mileage Components
	52	Two Lane Rural	of Minimum Travel Distance
	53	Multi-Lane Rural	From Interchange To Urban
	54	Urban 4-Lane	Center Card
3-6	See Interchange Number Listing		
7-10	Appropriate Component Distance From Interchange To Urban Center 1		
11-14	Appropriate Component Distance From Interchange To Urban Center 2		
15-18	Appropriate Component Distance From Interchange To Urban Center 3		
19-22	Appropriate Component Distance From Interchange To Urban Center 4		
23-26	Appropriate Component Distance From Interchange To Urban Center 5		
27-30	Appropriate Component Distance From Interchange To Urban Center 6		
31-34	Appropriate Component Distance From Interchange To Urban Center 7		
35-38	Appropriate Component Distance From Interchange To Urban Center 8		
39-42	Appropriate Component Distance From Interchange To Urban Center 9		
43-46	Appropriate Component Distance From Interchange To Urban Center 10		
47-50	Appropriate Component Distance From Interchange To Urban Center 11		
51-54	Appropriate Component Distance From Interchange To Urban Center 12		

CARDS 61,62,63,64 Measured Distances From Urban Centers To Interchanges

COLUMN(S)	CODE	DESCRIPTION	
1-2	61	Interstate	Highway Mileage Components
	62	Two Lane Rural	of Minimum Travel Distance
	63	Multi-Lane Rural	From Interchange To Urban
	64	Urban 4-Lane	Center Card
3-6	See Interchange Number Listing		
7-10	Appropriate Component Distance From Interchange To Urban Center 13		
11-14	Appropriate Component Distance From Interchange To Urban Center 14		
15-18	Appropriate Component Distance From Interchange To Urban Center 15		
19-22	Appropriate Component Distance From Interchange To Urban Center 16		
23-26	Appropriate Component Distance From Interchange To Urban Center 17		
27-30	Appropriate Component Distance From Interchange To Urban Center 18		
31-34	Appropriate Component Distance From Interchange To Urban Center 19		
35-38	Appropriate Component Distance From Interchange To Urban Center 20		
39-42	Appropriate Component Distance From Interchange To Urban Center 21		
43-46	Appropriate Component Distance From Interchange To Urban Center 22		
47-50	Appropriate Component Distance From Interchange To Urban Center 23		
51-54	Appropriate Component Distance From Interchange To Urban Center 24		

CARDS 71,72,73,74 Measured Distances From Urban Centers To Interchanges

COLUMN(S)	CODE	DESCRIPTION	
1-2	71	Interstate	Highway Mileage Components
	72	Two Lane Rural	of Minimum Travel Distance
	73	Multi-Lane Rural	From Interchange To Urban
	74	Urban 4-Lane	Center Card
3-6	See Interchange Number Listing		
7-10	Appropriate Component Distance From Interchange To Urban Center 25		
11-14	Appropriate Component Distance From Interchange To Urban Center 26		
15-18	Appropriate Component Distance From Interchange To Urban Center 27		
19-22	Appropriate Component Distance From Interchange To Urban Center 28		
23-26	Appropriate Component Distance From Interchange To Urban Center 29		
27-30	Appropriate Component Distance From Interchange To Urban Center 30		
31-34	Appropriate Component Distance From Interchange To Urban Center 31		
35-38	Appropriate Component Distance From Interchange To Urban Center 32		
39-42	Appropriate Component Distance From Interchange To Urban Center 33		
43-46	Appropriate Component Distance From Interchange To Urban Center 34		
47-50	Appropriate Component Distance From Interchange To Urban Center 35		
51-54	Appropriate Component Distance From Interchange To Urban Center 36		

CARDS 81,82,83,84 Measured Distances From Urban Centers To Interchanges

COLUMN(S)	CODE	DESCRIPTION	
1-2	81	Interstate	Highway Mileage Components
	82	Two Lane Rural	of Minimum Travel Distance
	83	Multi-Lane Rural	From Interchange To Urban
	84	Urban 4-Lane	Center Card
3-6	See Interchange Number Listing		
7-10	Appropriate Component Distance From Interchange To Urban Center 37		
11-14	Appropriate Component Distance From Interchange To Urban Center 38		
15-18	Appropriate Component Distance From Interchange To Urban Center 39		
19-22	Appropriate Component Distance From Interchange To Urban Center 40		
23-26	Appropriate Component Distance From Interchange To Urban Center 41		
27-30	Appropriate Component Distance From Interchange To Urban Center 42		
31-34	Appropriate Component Distance From Interchange To Urban Center 43		
35-38	Appropriate Component Distance From Interchange To Urban Center 44		
39-42	Appropriate Component Distance From Interchange To Urban Center 45		
43-46	Appropriate Component Distance From Interchange To Urban Center 46		
47-50	Appropriate Component Distance From Interchange To Urban Center 47		
51-54	Appropriate Component Distance From Interchange To Urban Center 48		

APPENDIX D

ADT EXPANSION FACTORS

FACTORS TO EXPAND 24-HOUR WEEKDAY (MON., TUES., WED., THUR.) VOLUMES TO A.D.T. 1970-1969-1968-1967

GROUPS	MONTHS OF YEAR											
	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
GROUP I	STATE ROADS IN MOST RURAL AREAS											
1970	1.332	1.252	1.159	1.148	1.063	0.959	0.912	0.920	1.026	1.073	1.169	1.111
1969	1.350	1.250	1.198	1.109	1.082	0.951	0.927	0.911	1.043	1.060	1.113	1.155
1968	1.297	1.266	1.212	1.103	1.073	0.978	0.935	0.914	1.040	1.075	1.124	1.176
1967	1.320	1.320	1.218	1.130	1.053	0.973	0.939	0.927	1.051	1.097	1.154	1.153
GROUP II	STATE ROADS IN RURAL RESORT AREAS											
1970	1.485	1.499	1.398	1.246	1.115	0.938	0.875	0.807	1.126	1.234	1.251	1.257
1969	1.477	1.439	1.374	1.226	1.127	0.944	0.873	0.870	1.199	1.235	1.393	1.335
1968	1.452	1.444	1.373	1.212	1.125	0.949	0.845	0.864	1.127	1.212	1.298	1.345
1967	1.514	1.558	1.377	1.222	1.165	0.939	0.870	0.885	1.161	1.245	1.356	1.313
GROUP III	STATE ROADS IN MINING AREAS											
1970	1.320	1.209	1.126	1.043	1.002	0.965	0.942	0.912	0.988	1.000	1.036	1.029
1969	1.161	1.059	1.058	1.030	0.992	0.957	0.940	0.931	0.962	1.031	1.094	1.079
1968	1.187	1.110	1.063	0.997	0.956	0.959	0.925	0.968	0.977	0.983	1.053	1.057
1967	1.119	1.123	1.033	0.986	0.973	0.963	0.964	0.956	0.942	0.991	1.079	1.058
GROUP IV	STATE ROADS IN SUBURBAN AREAS											
1970	1.208	1.144	1.031	1.067	0.988	0.950	0.942	0.938	0.919	0.943	0.970	0.985
1969	1.239	1.141	1.071	1.025	0.954	0.949	0.931	0.925	0.967	0.984	1.007	1.028
1968	1.204	1.148	1.109	1.061	1.017	0.988	0.989	0.983	1.015	1.008	1.008	1.030
1967	1.135	1.172	1.043	1.010	1.059	0.960	0.959	0.966	1.017	1.059	1.093	1.056
GROUP V	LOCAL ROADS IN RURAL AREAS											
1970	1.199	1.112	1.074	0.971	0.973	0.900	0.892	0.936	0.943	0.939	0.965	1.017
1969	1.198	1.101	1.070	1.001	0.962	0.901	0.921	0.960	0.965	0.957	1.006	1.008
1968	1.206	1.091	1.064	0.990	0.979	0.896	0.932	0.929	1.003	0.965	0.981	1.037
1967	1.160	1.146	1.058	1.015	0.957	0.863	0.901	0.958	1.076	1.018	1.001	1.045

FIGURE D-1. VOLUME ADJUSTMENT FACTORS

FACTORS TO EXPAND 24-HOUR WEEKDAY (MON., TUES., WED., THUR.) VOLUMES TO A.D.T.

1964, 1965, 1966

GROUPS	MONTHS OF YEAR											
	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
GROUP I	STATE ROADS IN MOST RURAL AREAS											
1964	1.332	1.311	1.217	1.132	1.068	0.965	0.925	0.918	1.014	1.077	1.188	1.172
1965	1.300	1.318	1.230	1.118	1.055	0.960	0.925	0.910	1.022	1.100	1.152	1.179
1966	1.321	1.333	1.226	1.110	1.098	0.971	0.928	0.918	1.029	1.098	1.170	1.133
GROUP II	STATE ROADS IN RURAL RESORT AREAS											
1964	1.608	1.562	1.417	1.308	1.170	0.937	0.861	0.867	1.108	1.299	1.367	1.449
1965	1.562	1.567	1.431	1.300	1.152	0.929	0.847	0.859	1.088	1.255	1.359	1.379
1966	1.513	1.540	1.409	1.208	1.133	0.934	0.873	0.796	1.105	1.324	1.427	1.439
GROUP III	STATE ROADS IN MINING AREAS											
1964	1.159	1.167	1.111	0.997	0.965	0.967	0.912	0.872	0.970	0.989	1.054	1.029
1965	1.141	1.167	1.098	0.932	0.948	0.984	0.919	0.976	0.989	0.993	0.998	1.017
1966	1.184	1.203	1.148	1.025	0.985	0.910	0.911	0.901	1.077	0.923	0.997	1.037
GROUP IV	STATE ROADS IN SUBURBAN AREAS											
1964	1.223	1.169	1.118	1.044	1.007	0.967	0.940	0.938	0.963	1.011	1.054	1.090
1965	1.172	1.218	1.128	1.036	1.007	0.956	0.939	0.934	0.985	1.020	1.030	1.075
1966	1.188	1.206	1.125	1.050	1.031	0.932	0.936	0.937	1.002	1.055	1.076	1.041
GROUP V	LOCAL ROADS IN RURAL AREAS											
1964	1.292	1.224	1.101	1.026	0.958	0.907	0.910	0.913	1.044	1.044	1.049	1.055
1965	1.150	1.223	1.076	0.996	0.928	0.892	0.897	0.933	1.096	1.030	1.009	1.065
1966	1.157	1.152	1.039	1.015	0.945	0.878	0.914	0.954	1.060	1.009	1.028	1.052

FIGURE D-2 VOLUME ADJUSTMENT FACTORS

APPENDIX E

STATISTICAL PLOTS FOR THE LAND USE DEVELOPMENT MODEL

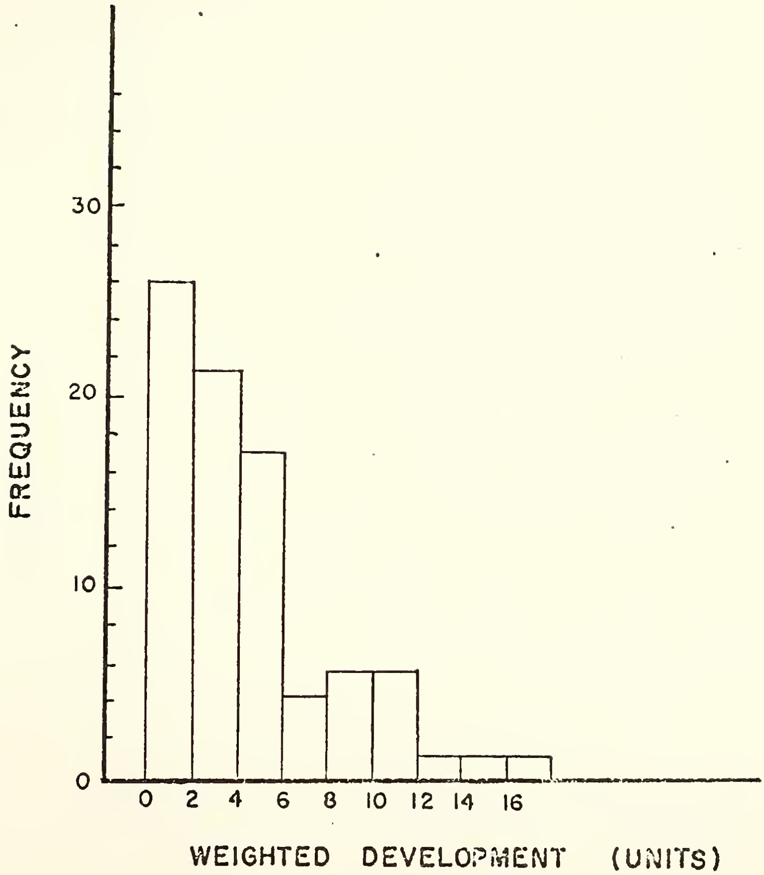


FIGURE E-1. HISTOGRAM OF WEIGHTED DEVELOPMENT
82 CASES

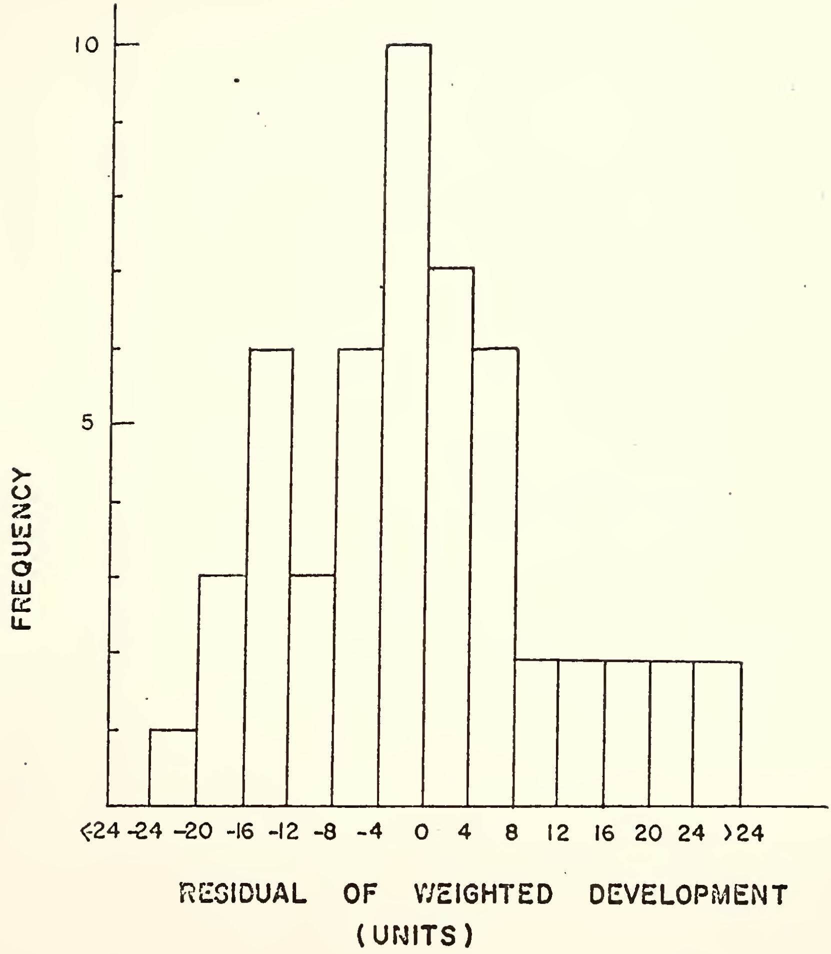


FIGURE E-2. RESIDUAL HISTOGRAM FOR FINAL WEIGHTED MODEL WITH 52 CASES

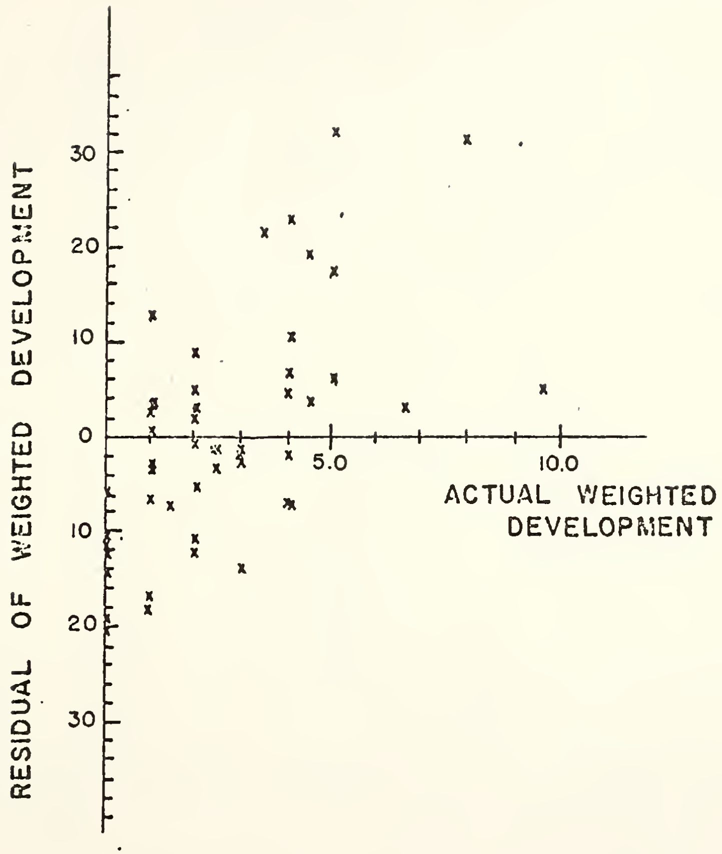


FIGURE E-3. RESIDUALS VERSUS $\hat{Y}_i$ FOR 52 CASES